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SLIDING CRANE FOR MOBILE SCISSOR LIFT TABLE

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Abstract:

The purpose of this report is to build a device that can be installed to the hydraulic lifting cart to help students work easily on the CNC machine. The main point of the proposal is to design a device that can carry, load, and unload the Kurt vise, which weighs over 80 lb., to the CNC machine table and to the storage area within fifteen minutes during lab time. The methodology of the report focuses on the safety and easy performance for students working in the machine shop. Safety is the main concern in the design of this project, because the device works with heavy, unwieldy loads in a high risk area. From the result of testing the device, the device is balanced and performs excellently with CNC vises of multiple sizes and shapes. The device is also being tested on the AutoCAD Simulation Mechanical program to qualify the safety before the devices is used in the lab. The main issue of the device during manufacturing and performance is that the device is heavy, even though the model was re-designed three times to make the device more efficient. Due to the safety factor of the design, the device is required to be built with steel A36 square tubes (3 x 3 in.) with a 0.25 in. thickness. Additionally, two machinists are required to operate the device safely while loading and unloading the vise to the CNC machine table.

Introduction

Motivation

The Central Washington University Machine shop needs a device that helps instructors and students transfer Computer Numerical Control (CNC) vises and jars to the vertical CNC milling machines' tables safely and easily for students who have less experience with the machine. The device must be able to lift up the vise that helps machinist clean out metal chips under it and avoid metal corrosion from the coolant liquid. The project is given by Mr. Ted Bramble, Mechanical Engineering Technology (MET) instructor and Mr. Matt Burvee, Instructional Lab Technician.

The project was approved and got advised by Mr. Bramble, Mr. Burvee, Professor Pringle, Professor Beardsley, and Professor Johnson from the Mechanical Engineering Department, of CWU. The idea, manufacturing, and testing of the project are worked by Phuc Chau, the MET student.

Function

The main functions of the device are used to load, unload, and transfer the CNC vise from shelves in the Hogue machine lab to the CNC machine table and vise versa. The device is required to lift up the Kurt CNC vise and be able to dry out the coolant water and metal chips sticking under the surface of the vise.

Requirements

The requires of the projects are as follows:

- The device can lift up and carry 80 lbs. Kurt CNC vise
- The life time cycle is at least 10 years.
- Safety Factor is 1.5.
- The maximum cost of the project is $600.
- The time performance of load and unload of the vise from shelf to the CNC table in less than fifteen minutes.

Engineering Merit

In this design, the cause of moment is the main calculation of the project because the forces acting on the cart must cancel each other out. Thus, the sum of moment on the cart must be zero to avoid the stiff over of the cart when the Kurt vise is hanging on the crane. Because of that, the equation 1-1 is used to find the moment of the vise when it is hanging on the crane.

$M = F * d$ with M: Moment (lb.-in) (1-1)

F: Force (lb.)

d: Distance (in)

With the moment force on the I-beam, the normal bending stress is calculated from the equation 1-2. After the bending normal stress is defined, the designer can find the size and the material of I-Beam is matched with calculated normal stress.

$\sigma_{normal} = \frac{Mc}{I} = \frac{M}{S}$ with σ: Normal stress (psi) (1-2)

M: Moment (lb-in)

I: Moment Inertia (in^4)

c: radius of I-beam (in)

$S = \frac{I}{c}\,(in^3)$

The maximum stress allowed is calculated from the equation (1-3). After the design stress is calculated, the maximum allowable stress is calculated from the design stress.

$\sigma_{allow} = SF * \sigma_{normal}$with SF: safety factor given (1-3)

After the stress is defined, the deflection of the I-Beam is calculated. The main reason of finding the deflection is because the designer can look for the size and material of the I-Beam.

$y = \frac{-PL^3}{3E}$ with P: Force applied on the beam (lb.) (1-4)

L: Distance of the fixed pin to force applied (in)

I: Moment Inertia (in^4)

E: Modulus Elasticity (psi)

Scope of Effort

The project upgrades the mobile scissor lift table in the machine shop. Because of that, the frame is built to help carry and hold the vise. The project can be worked on by one person. Additionally, Mr. Burvee will help with welding parts together, and Professor Pringle is a mentor of the project.

Success Criteria

The device is used in the machine shop, helps students and instructors lift the Kurt vise. It helps reduce the time of load and unload to the CNC machine table, and reduces the risks of accidents if students drop the vise.

Success Scenario

The device will be presented at SOURCE 2017, Symposium of University Research & Creative Expression. The research is submitted to Scholar Work which improves resources for mechanical engineering students. The research help Chau gain experience in design, manufacturing, and writing report processes.

DESIGN AND ANALYSIS

Approach: Proposed Solution

At the beginning, the design of the device was changed a couple of times to get the approval from Mr. Bramble and Mr. Burvee.

First Design

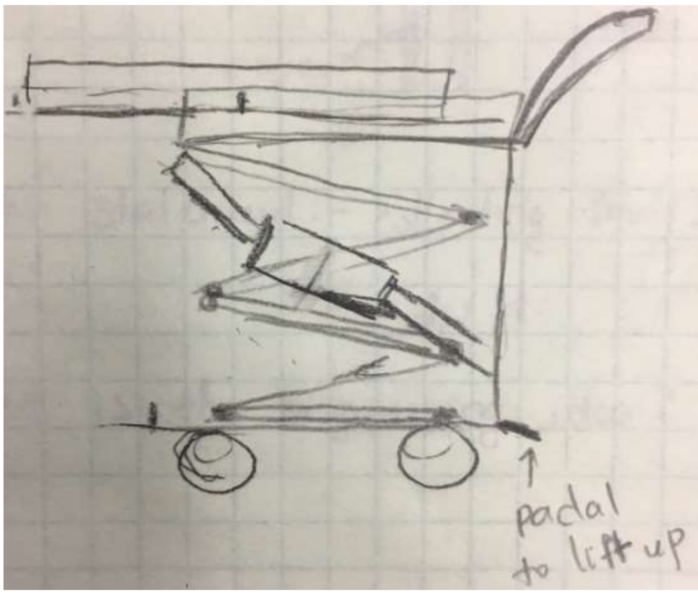

Figure 1: Design 01

The design is able to slide the vise to the CNC table, but machinist must pick up the vise. Because of that, the design must change.

Second Design

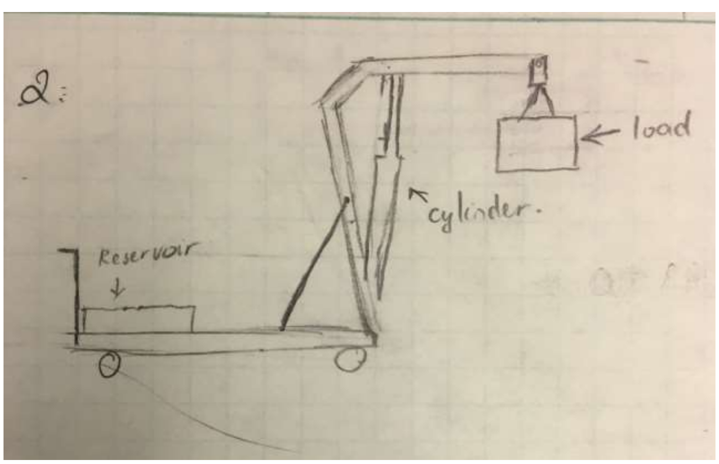

Figure 2: Design 02

It is not an appropriate design for the devise because the department allows the use of the mobile scissor lift table, and they do not plan on buying another table to use. Also, the height to reach different shelves in the machine shop and the CNC table is limited. The cost of the cylinder is over the price allowable from the department. As the result, the design is redesign again.

Third Design

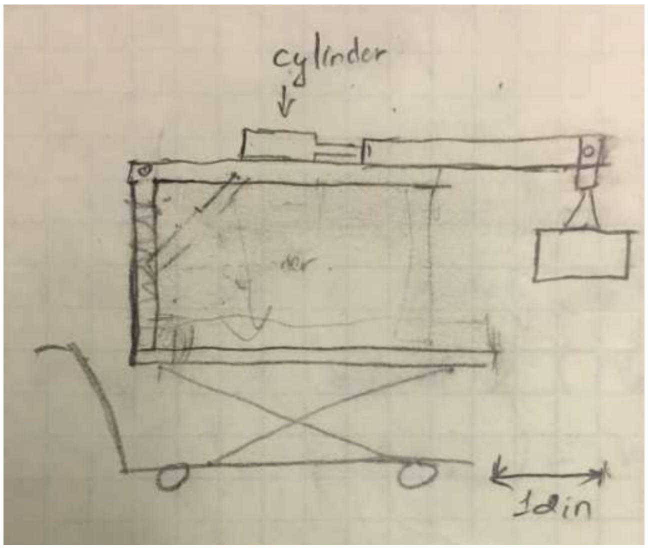

Figure 3: Design 03

For this design, the main problem came from the cylinder. Mr. Burvee and Mr. Bramble said that the cart couldn’t apply more reservoir because if Chau adds the cylinder, the device must rebuild the whole system. That takes a lot of time to build the system and not appropriate to use in the machine shop.

Fourth Design

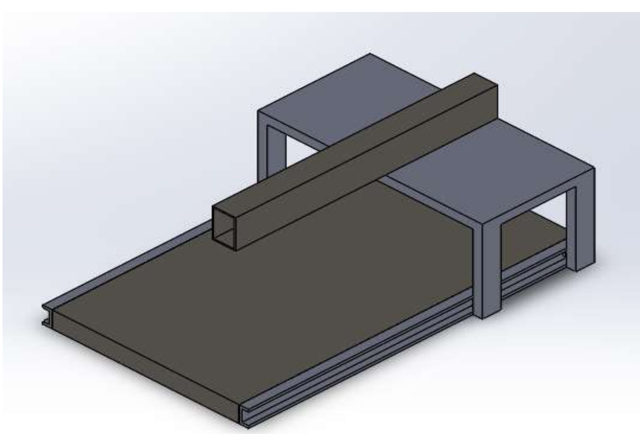

Figure 4: Design 04

Because of all the previous design problems, the new design is changed to a basic mechanical design with a sliding frame where the square tube will hold the vise and transfer it to the CNC table. However, the table weight is too heavy for the cart, and there are no legs to connect to the table. The square tube is not stronger than the I-beam when it is holding the vise.

Fifth Design

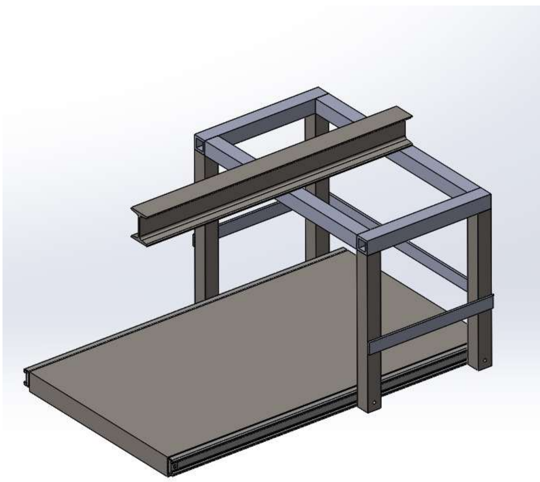

Figure 5: Design 05

The final design is approved by Mr. Bramble and Mr. Burvee. The table is changed to be a frame made by a square tube. The holder is changed to be an I-beam, the size and material is calculated in the appendixes. The side mount track roller will be purchased from McMaster Carr.

Design Description

The design contains three major components: frame, I-beam with spreader lifting bars, and side-mount track and roller. The square tube and I-Beam material is an A36 steel because of cost.

The final design of the device is that the frame is supported the I-beam when the I-beam hold the Kurt vise. The frame is welded together by square tubes and the I-Beam is welded on the top of the frame. On the side of the table, the steel side mount trackers are welded to two sides of the table. The side-mount track roller is attached to each leg of the frame to help roll the frame back and forth, which helps transfer the vise smoothly from the shelf to the CNC machine table.

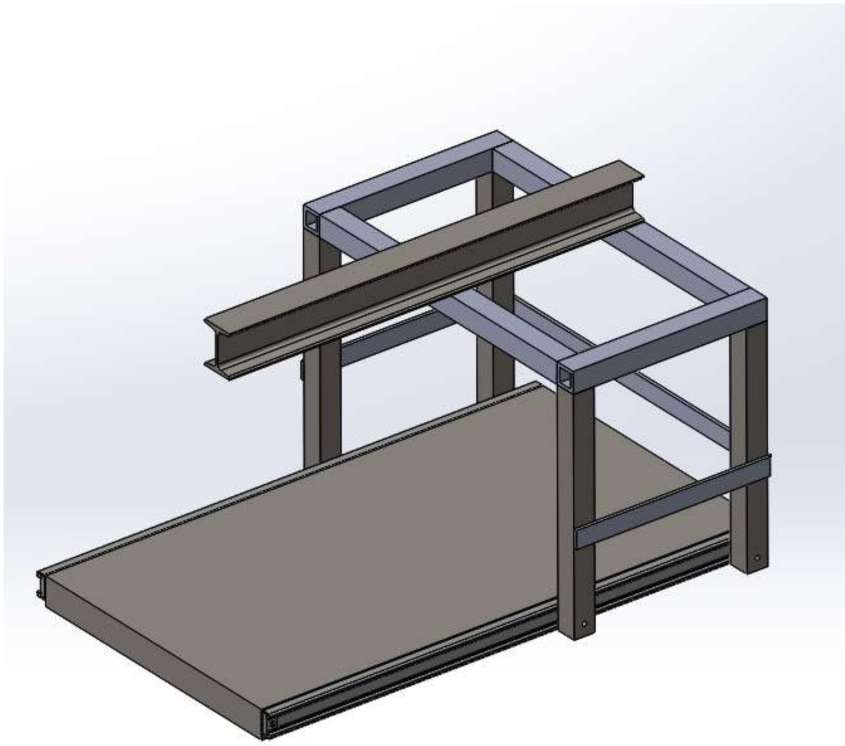

Figure 6: Final Design

Benchmark

After looking up some several sources on the internet selling cranes and hoists, there aren't any companies making good designs for the device being used in the machine shop. Some designs do not have wheels, so they cannot deliver the vise from place to place. Some designs are able to transport, but the size and shape is big and tall, so they do not fit in the machine shop because it requires a small space to fit in.

Figure 7 shows the device which is the most similar to the engineering requirements. However, the device cannot roll the CNC vise and drop it on the CNC table. Furthermore, the price of the device is so expensive. It costs $1,869.99 (Northern Tool + Equipment).

The advantages of the device are that it is mobile and has a high weight capacity. The disadvantages of the device are that it is expensive, unable to load the vise onto the table, and that it does not hold the vise securely enough.

Figure 7: Genie Super Hoist Lift - 300-lb. Load Capcity, 12ft. 5 1/2 in. lift Height, Model# GH 3.8. Source: NORTHERN TOOL + EQUIPMENT

Performance Prediction

The device is predicted to work for 10 years with the room temperature conditions. In addition, when it performs, the device requires two machinists working together to install and uninstall the CNC vise to the CNC machine table.

The cost of the project is estimated to be around $500 including purchasing prices. The cost does not count for the labor cost and some parts donated from the MET department.

Analyses

In this section, the I-beam used the Autodesk Simulation Mechanical program to analyze the deflection and maximum stress bending acting on the I-Beam. The force acting on the end of the I-beam is 120 lbs. because the Kurt vise weights 80lbs. With 1.5 safety factor, the total force acting on the I-Beam is 120 lbs.

Figure 8 shows the I-beam is set up in the Finite Element Analysis (FEA) method in 3D. The beginning of the I-beam is set up fixed points, and the end of the I-beam is 120 lbs. point down in y-axis.

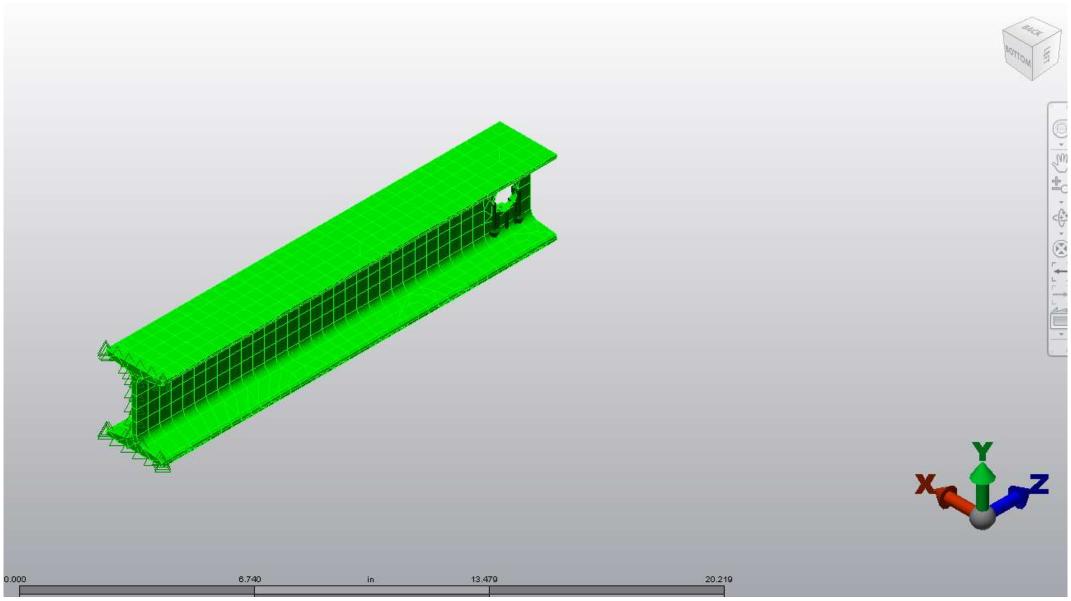

Figure 8: Set up I-Beam on the FEA program

Figure 9 shows the deflection of the I-Beam on the y-axis. The maximum deflection of the I-beam is 0.000229 in. As the result, the deflection is super small, so the I-beam will not break when the vise hangs on it.

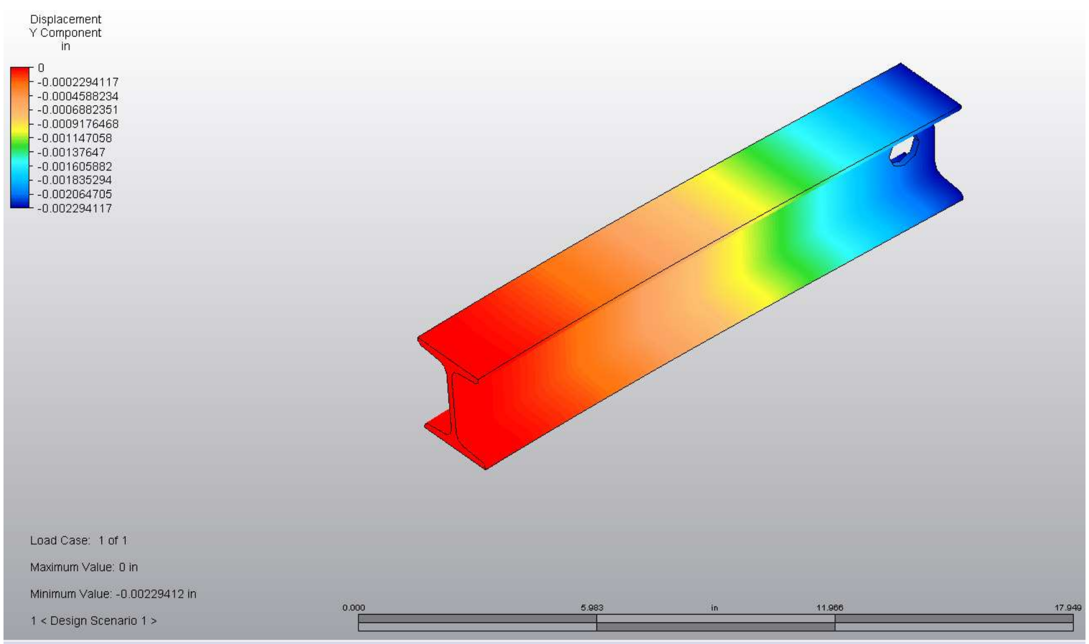

Figure 9: The deflection of I-Beam on the y-axis (in)

Figure 10 shows maximum Stress von Mises of the I-beam is 1,115.251 psi. According to the Stress von Mises, Chau can choose the size of the I-beam from the Mott textbook. After that, he will look up several online sources such as onlinemetal.com and Haskin Steel for manufacturing size of the I-Beam.

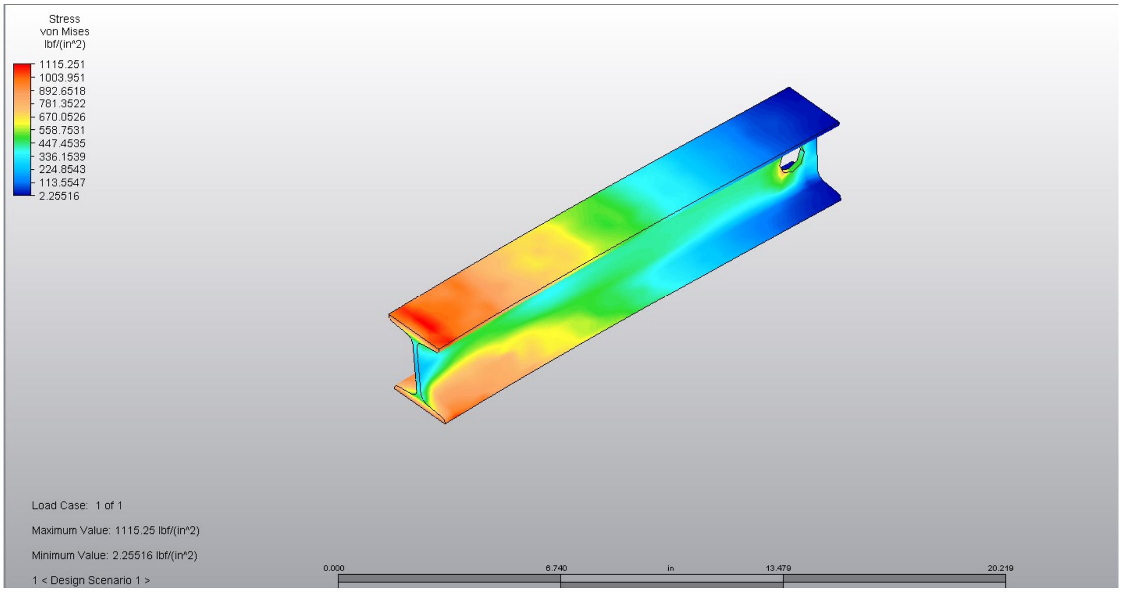

Figure 10: Stress Von Mises (psi)

Device: Parts, Shapes, and Conformation

The parts drawings and a final assembly drawing are attached on the appendix B of the proposals.

Tolerance

According to the Mott textbook, the tolerance of cutting square tube and flat bar is +/- 1/32 in, and the tolerance of drill hole on square tube is +/- 0.005 in.

CONSTRUCTIONS

Description

In this project, the I-Beam, supporting frame flat bar, and frame square tubes material is A-36 steel. They are purchased from Haskins Steel.

The side-mount trackers, side-mount track rollers, and end stop side-mount track rollers are purchased from McMaster Carr. Because they come as a kit, the designer cannot make a part of the kit rather than purchasing all of them.

Drawing Tree

The graphic below, figure 11, shows assembly instruction for the frame. There are three main parts of the proposal: frame, I-beam, and side-mount track.

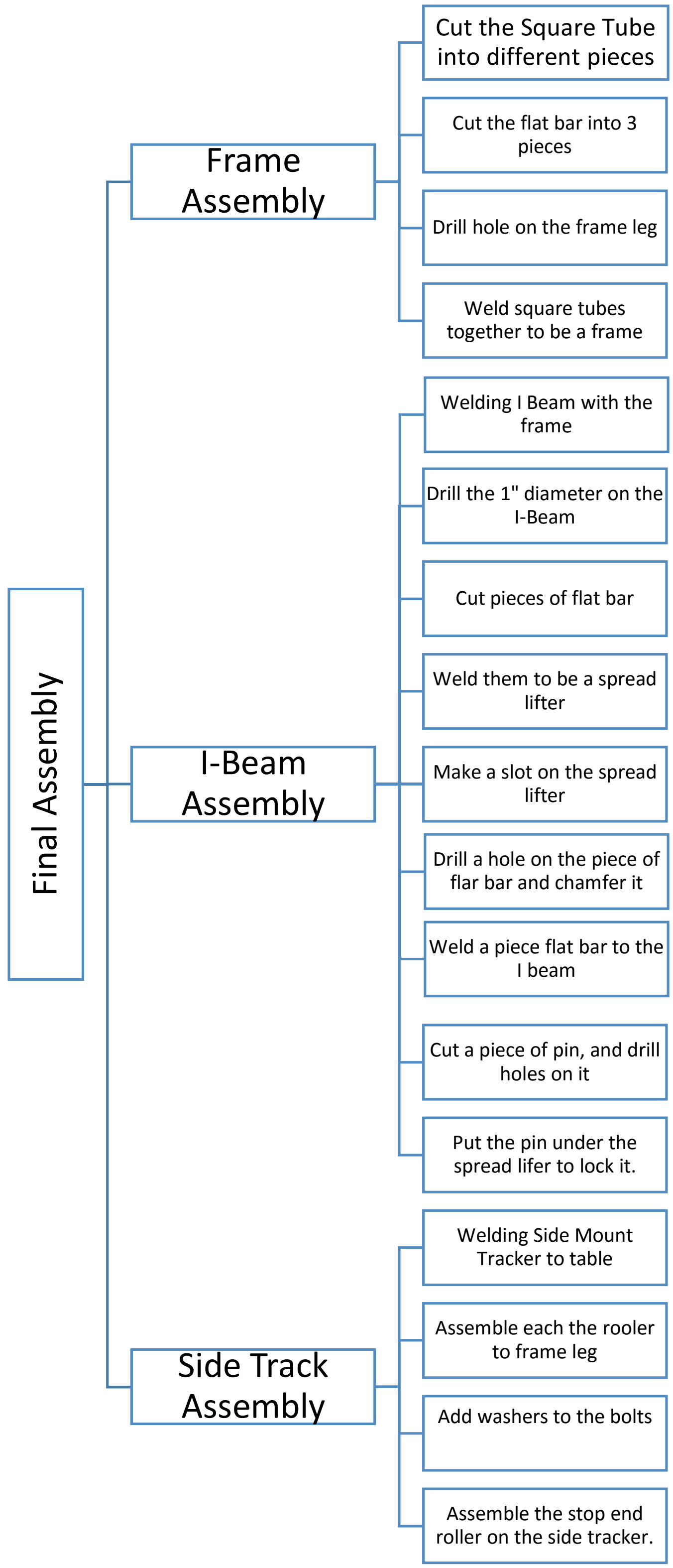

Figure 11 Drawing Tree

Part lists

List	Description	Quantity	Company	Part Number	Length
1	Standard I-Beam S3x3 Depth, 3/16 thick	1	Haskins Steel		2.5 ft.
2	Square Tube 1.5 x1.5 x 1/4”	1	Haskins Steel		12 ft.
3	Flat Bar (1/4 x 1–1/4”)	1	Haskins Steel		5 ft.
4	Overhead I-Beam Conveyor Component	1	McMaster Carr	5920K24	
5	Steel Side-Mount Track Roller	2	McMaster Carr	60135K13	
6	End Stop Side-Mount Track Roller	4	McMaster Carr	60135K12	
7	Washer	8	Free		
8	Side-Mount Track Roller	4	McMaster Carr	60135K71	

Manufacturing issues

During the manufacturing project, many issues were identified, solved by discussion with Mr. Burvee and Mr. Bramble.

Cutting the square tube is a little off set from the requirement. The requirement of the leg in the frame is 16 in. There are three legs cut perfectly to 16 in., but one leg is 15.9375 in., which is 1/32 in. off of the tolerance. The leg will make the frame unbalanced on the top. To solve problem, Mr. Burvee will add a small piece of metal when he welds the pieces together.

Figure 12: Cutting Square Tube

Drilling the hole on the square tube brings a lot of issues. All the holes on the square tubes are off-set from the requirement locations, but it is not a big issue because the roller will attach to the square tube. The holes are not drilled at the right location, and it is not appropriate in the manufacturing. However, the issue has no effect on the project.

Figure 13: Drill 0.3125 in on Square Tube

Figure 14: Supporting fram bar issue

The supporting frame bar was attached to the wrong place due to the miscalculation. Because of that, Mr. Burvee broke the connected joint on the frame and reattached the bar in the correct locations.

TESTING METHODS

Introduction

The purpose of this report is to build a device that can be installed to the hydraulic lifting cart to help students work easily on the CNC machine. The device is required to lift up variable sizes and shapes of CNC vises to the CNC milling table. Because of that, the main purpose of the testing device is focused on the balance of the cart while loading and unloading the CNC vises to the shelves in the machine shop. Balancing test is applied as the first test.

The second test applied to the device was the load and unload the CNC vise test. To pass the test requirement, the device must be able to get the CNC vise on the shelves and load to the CNC tables in the machine shop.

Prediction

The predicted performance of this test is around 50 lbs. because the moment force from calculation causes fatigue of 50lbs. The second test predicts the device can load and unload the CNC vise within 15 minutes. Because the total lab hours is two hours, it is an appropriate setup time.

Method/ Approach

i) Balance Test 01

The Kurt Vise is hanging on the frame, and facing forward to the table in the machine shop. The force is applied from the handle by the tester. In each test, the tester will add 10 lbs. until the cart is lifted up. The frame is moved to the beginning, middle and the end of the cart. As the result, the tester wants to find how much force will cause the moment force to the cart.

ii) Load and Unload Performance Test

For this test, the device is tested by loading and unloading the Kurt CNC vise to the different CNC vertical milling machines. The load and unload test performs excellently. Because of that, the time performance is recorded as a data for this test. The predicted time is 15 minutes. The load and unload test is repeated 10 times from different shelves to different CNC machines in the machine shop.

Procedures

i. Balance test 01

Where: Machine shop

Time: Two hours

1. Step 01: Drive the cart to the shelf and park perpendicular with the shelf.
2. Step 02: Use your foot to step on the paddle to raise the table up to the position wanted.
3. Step 03: Use ½ inch helix bolts placed next to the CNC Milling machine.
4. Step 04: Thread the bolts to hole from the CNC vise.
5. Step 05: Steps on the paddle and lift up the jaws.
6. Step 06: Push back the cart and release oil back to reservoir.
7. Step 07: Drive the cart to the table next to the gear-maker machine and park it perpendicular to the table.
8. Step 08: Use the paddle to lift up the surface table to the same height as the table.
9. Step 09: Use electric scale and hook it to the handle.
10. Step 10: Pull up the scale in different amounts of force (10lbs, 15lbs, 20 lbs, 25 lbs, 30 lbs, …,) until the cart's wheels fall off the ground.
11. Step 11: Record data of weights.
12. Step 12: Repeat step 09 to step 10 when putting the frame rolling in different locations on the cart.

ii. Load and unload performance test

Where: Machine shop

Time: 2 hours

1. Step 01: Drive the cart to the shelf and park perpendicular with the shelf.
2. Step 02: Use your foot to step on the paddle to raise the table up to the position wanted.
3. Step 03: Use ½ inch helix bolts placed next to the CNC Milling machine.
4. Step 04: Thread the bolts to hole from the CNC vise.
5. Step 05: Steps on the paddle and lift up the jaws.
6. Step 06: Push back the cart and release oil back to reservoir.
7. Step 07: Drive the cart to the table next to the gear-maker machine and park it perpendicular to the table.
8. Step 08: Use the paddle to lift up the surface table to the same height as the table.
9. Step 09: Slide the frame on the table.
10. Step 10: Release the oil brake on the cart to make the table lower than the CNC.
11. Step 11: The CNC vise lies on the CNC table.
12. Step 12: Unscrew helix bolts and pull back the cart.

Results

i. Balance Test

Position	Force Pulls up	Pass	Fail
Beginning of the cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb	x	
	60 lb	x	
	70 lb	x	
	80 lb	x	
Middle of the Cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb	x	
	60 lb	x	
	70 lb		x
	80 lb		x
End of the cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb		x
	60 lb		x
	70 lb		x
	80 lb		x

The table above shows data taken when the cart is used to lift different amount of force to find the balance. Pass means the frame does not roll. Fail means the frame rolls and the vise drops on the table.

The most difficult thing in the test is lifting the scale up by hand. The scale handle is small and hard to hold to apply the right force. As the result, the force applied can't be exactly correct.

ii. Load and Unload Performance Test

For the second test, the cart is tested by loading and unloading the CNC vise. The cart performed well, so a time requirement was added: the cart should be loaded and unloaded in less than fifteen minutes. The data below shows the time performance of loading and unloading the CNC vise to CNC machine table.

The column charts below show the time performance of each trial to different machines and shelves in the machine shop. Figure 15 shows the result of the test between the farthest shelf and farthest CNC machine in the machine shop. The total average of the time taken to load and unload the CNC vise to the machine is 3 minutes and 30 seconds. Compared with the prediction time, it's three times less than the requirement time.

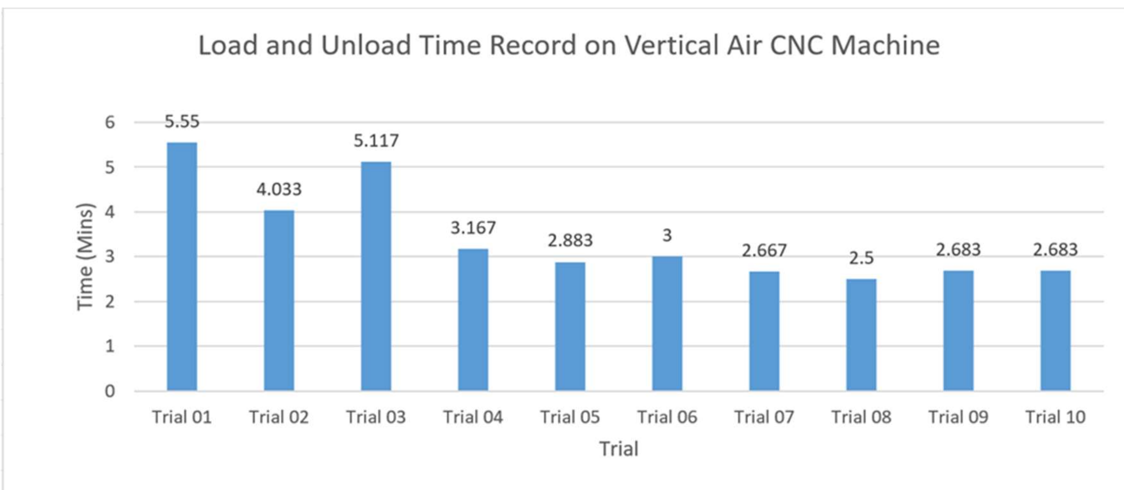

Figure 15: Test from the furthest shelf to the furthest CNC Milling machine

Figure 16 shows the result of the test between the shortest shelf and shortest CNC machine in the machine shop. The total average of the time taken to load and unload the CNC vise to the machine is 2 minutes and 20 seconds.

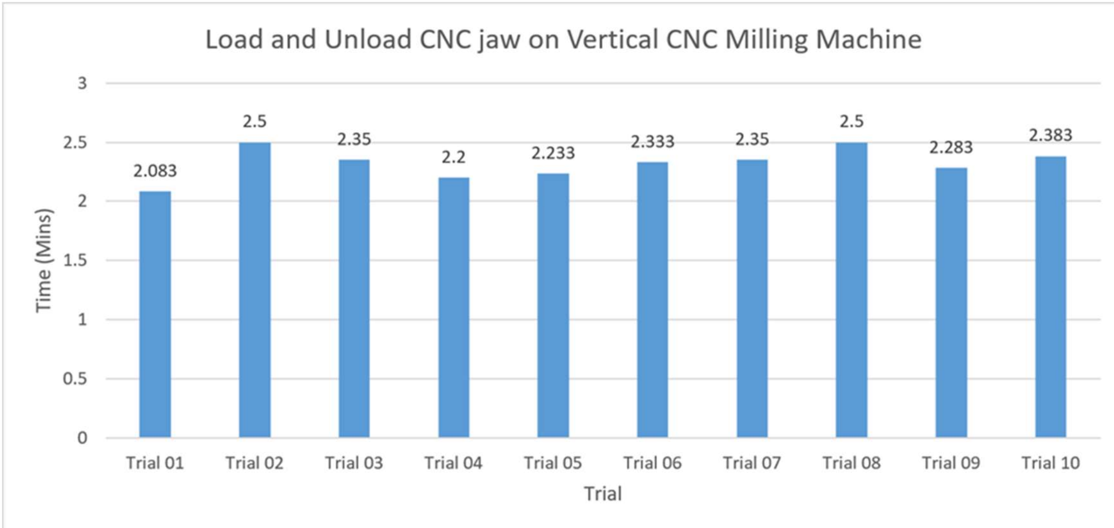

Figure 16 The time traveling from the shortest shellf to the shortest CNC machine table

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Budget

The cost of the project is funded by the Mechanical Engineering Department. The designer is able to use some of the materials in the machine shop. By calculating the cost of parts in appendix D, the total cost is assumed to be $339.10 for the project.

Schedule

In the general idea of the project, the three main parts are divided into three quarters of school. In Fall quarter, the designer brainstormed, figured out engineering problems, and wrote the proposal. In Winter quarter, the designer worked on manufacturing and ordered materials. In Spring quarter, the project was finished and ready to test for the safety features and failure test. The grant chart of each quarter is attached on appendix E.

Project Management

i. Human Resources

Ted Bramble is the manager of the project. He is in charge of the proposal, working on the design, and manufacturing the project.

Matt Burvee is the MET lab technician. He helps with manufacturing process and gives feedback and advises on project.

Professor Pringle is the mentor of the project. He helps with calculations, information needed, and advises the organizer of the proposal.

ii. Physical Resources

The machine lab and welding lab are the main places to work on the project. The machine lab is used to cut material, sand material, and drill the holes. The welding lab is used to weld the square tube together to make a frame.

iii. Soft Resources

The Solid work software is a useful program that is used a lot in the project. It is a 3-Dimention program and can extend to the ANSI drawing. Microsoft Office is used to work on the proposal, grant chart, time management, and presentation. In addition, the Autodesk Simulation Mechanical Program is used for 2-D and 3-D modeling testing. It helps the designer find out the deflection and stress analysis before building the project.

iv. Financial Resources

The budget of the project is from the Mechanical Engineering Department because the student built the project to support the machine lab. The project is funded and approved by Mr. Bramble and Mr. Burvee.

DISCUSSION

The main purpose of the project is to help MET students and faculties carry the heavy tool and slide to the CNC table. When the tool is lifted up, students can dry out the surface below the tool to prevent corrosion. Also, by cleaning out the surface below the tool, students can clean out the metal chips to manufacture the parts accurately.

Design Evolution/Performance Creep

During the design time of the project, the design ideas were changed five times before the final design because of the cost of parts, and because for the hydraulic cart was difficult to fit in the lab.

Project Risk Analysis

The largest risk of the project was to keep the cart balanced because the designer doesn't build up the whole cart system. His design upgraded the cart in the machine shop to work better with heavy tools.

Testing Issues

According to the testing predicted calculation, the cart can get stiffed over with 414 lbs. of force. However, the maximum force that can be lifted with the cart is 80 lbs. In addition, when the tester lifted the cart, the cart wasn't stable.

CONCLUSION

In summary, the testing 01 is successful. The predicted force applied is only 40 lbs. because it doesn't require much force to lift up the cart. Mostly people use to roll the cart around the machine shop, so 40 lbs. as the small amount of force could not accidently happen when users lift up the cart and make it stiff over. In addition, the cart has a current heavy weight, so it can help the cart be balance itself even though there is force applied to lift it up. The test 02 is very successful. Testing the cart is repeated 20 times to load and unload the vise from shelf to the CNC machine table. The average time of the performance is around 3 minutes and 30 seconds maximum. It is really appropriate to help students use the cart in the lab to save time for installing the vise to the CNC machine table. Additionally, the cost of the project is $339.10, which is below the estimated budget for the project. Overall, the project is successfully made and performed in the machine shop, SOURCE, and senior project presentation.

ACKNOWLEDGEMENTS

It was an honor to work with Mr. Burvee , Mr. Bramble, and Professor Pringle. Without them, the project could not have been done on time. Additionally, many thanks to the Mechanical Engineering Department for sponsoring this project. It’s a big value of money and Chau was very appreciative for the sponsoring from the department.

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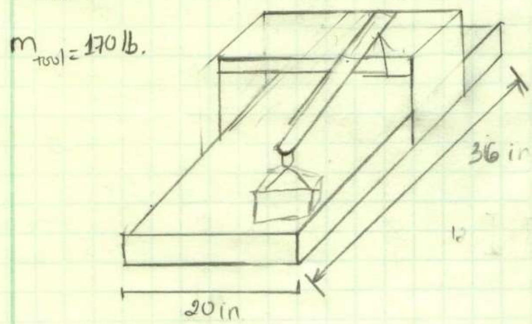
Appendix A – Analyses

A – 1: Calculate the force to avoid tip over and normal force at A

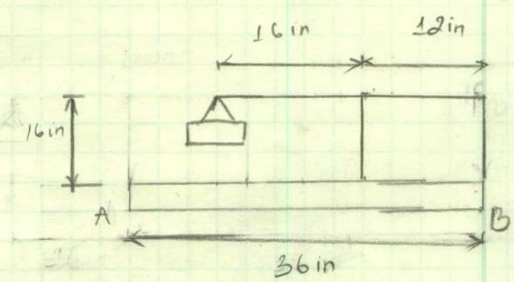
Phuc Chau | MET 495: Design | 11/14/2016 | 1/1

Given: A sliding ball bearings table is used to carry the CNC tool, lift up and delivery to the CNC machine table.

Picture is demonstrate below.



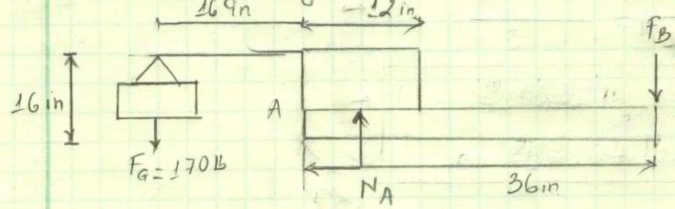
Side View



Find: Determine the force at point B when the sliding rods go to point A.

Solution:

Free body diagram when it slides to point A.



$$\circlearrowleft \Sigma M_A = 0 \Leftrightarrow -F_B \cdot 36\text{ in} + F_G \cdot 16\text{ in} = 0$$

$$\Leftrightarrow F_B = \frac{F_G \cdot 16\text{ in}}{36\text{ in}} = \frac{170\text{ lb} \cdot 16\text{ in}}{36\text{ in}}$$

$$\Leftrightarrow \boxed{F_B = 75,55\text{ lb}}$$

* Finding Normal force at A.

$$+\uparrow \Sigma F_y = 0 \Leftrightarrow -F_G + N_A - F_B = 0$$

$$\Leftrightarrow N_A = F_G + F_B = 170\text{ lb} + 75.56\text{ lb}$$

$$\Leftrightarrow \boxed{N_A = 245.56\text{ lb.}}$$

A – 2: Determine the bending stress of the beam

Phuc Chau | MET495: Design | 12/06/2016 | 1/2

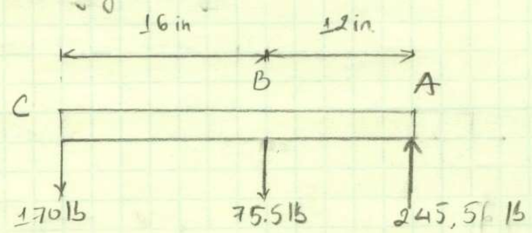
<u>Given</u>: A sliding rod like the previous problem. The rod is used to carry 170 lb CNC tool.

<u>Find</u>: Determine the bending stress of the tool acting on the beam.

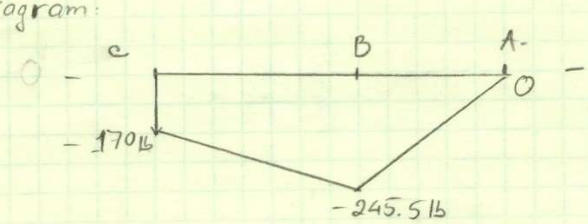
<u>Solution</u>:

In the problem, I find the bending stress of the beam acting on the holding slide.

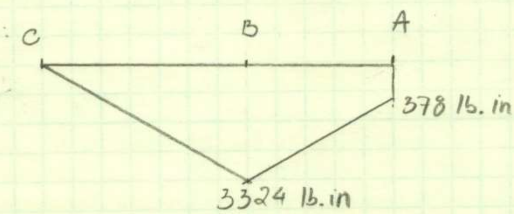
FBD:



Shear diagram:



Moment diagram:



According to the moment diagram, there is 378 lb.in at point A. Therefore, the beam is fail in design

⇒ To fix the problem, increasing the AB length, A – 2: Determine the bending stress (Continue)

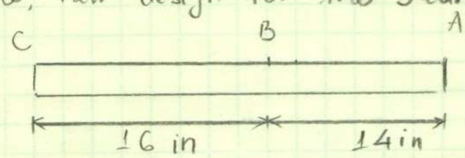
Phuc Chau. | MET 495: Design | 12/07/2016 | 2/2

* Finding new length for AB:

$M_{max} = F_A \times AB \Leftrightarrow AB = \dfrac{M_{max}}{F_A}$

$AB = \dfrac{3324 \text{ lb.in}}{245.5 \text{ lb}} \Leftrightarrow \boxed{AB = 13.54 \text{ in}}$

Hence, new design for the beam



* Finding bending stress of the beam.

$\sigma = \dfrac{Mc}{I}$ or $\sigma = \dfrac{M}{S}$ (Eq. 3-22, pg. 101, Mott textbook)

Using standard I beam for the beam. because I calculated on Excel file comparing with Hollow Square Tube, Hollow Rectangular Tube, and I beam.

Hence, my decision is using the I beam S 3 x 5.7.

Maximum bending stress:

$\sigma_{max} = \dfrac{M_{max}}{S}$ ($S_x = 1.68 \text{ in}^3$, Appendix Table 15-10, pg. 757, Mott textbook)

$\sigma_{max} = \dfrac{3324 \text{ lb.in}}{1.68 \text{ in}^3}$

$$\boxed{\sigma_{max} = 1,978.6 \text{ psi} \text{ or } 1.98 \text{ ksi}}$$

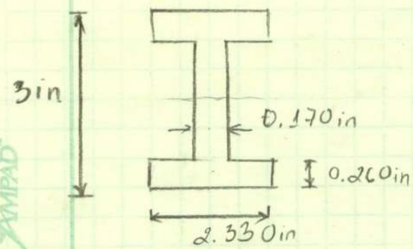
A – 3: Determine maximum direct shear stress and maximum vertical shear stress

Phuc Chau | MET495: Design | 12/07/2016 | 1/1

Given: The I beam beam is used to hold the CNC tool.

Find: Maximum direct shear, and verticle shear stress:

Solution: $V_{max} = 245.5$ lb (given, and solved in previous problem)



* Maximum direct Shear:

$\tau_{max} = \frac{V_{max}}{A}$ ($A = 1.67 in^2$ Table 15-10, pg. 757, Mott)

$\tau_{max} = \frac{245.5 lb}{1.67 in^2} \Leftrightarrow \boxed{\tau_{max} = 147 psi}$

* Finding maximum vertical shear stress:

$\tau_{max} = \frac{VQ}{It}$ (Eq. 3-16, pg. 98, Mott)

$Q = y_1 A_1 + y_2 A_2$ (Fig. 3-13 e, pg. 95, Mott)

$Q = \frac{0.260 in}{2} \times (2.330 in \times 0.260 in) + [(0.26 in + 0.620 in)(0.170 in \times 1.24 in)]$

$Q = 0.264 in^3$

$\tau_{max} = \frac{(245.5 lb)(0.264 in^3)}{(2.52 in^4)(0.170 in)}$

$\boxed{\tau_{max} = 151 psi}$

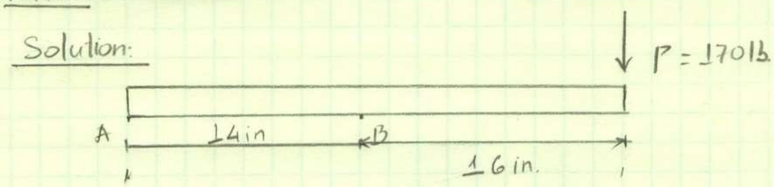
A – 4: Determine Bending Deflection of the I- Beam

Phuc Chau | MET 495: Design | 12/07/2016 | 1/1

Given: An I beam to hold the 170 lb CNC tool with 30 in length, and 3 in depth.

Find: The deflection of the I beam.

Solution:



The deflection of the beam:

$$y = \frac{-Px^2}{6EI}(3L - x) \quad \text{(Table A 14-2, pg. 741, Mott)}$$

$E = 30 \times 10^6$ psi (Appendix 3, pg 723, Mott)

$$y = \frac{-170lb \times (14in)^2}{6(30 \times 10^6 psi)(2.32 in^4)}(3 \times 30in - 14in)$$

$$\boxed{y = -0.0056 \text{ in.}}$$ Acceptable

A – 5: Force Balance

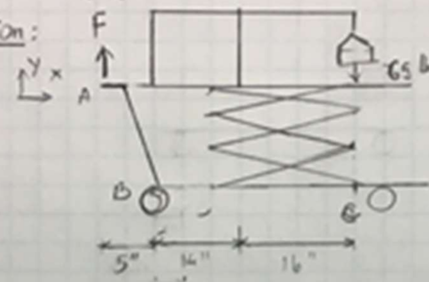
Phuc Chau | MET495C: Test 01 | 05/03/2017 1/

Given The frame is holding the CNC Kurt 6" vertical lock vise. The weight of the vise is 69 lb

Find Calculate the force make the cart stiff over when it's hanging on the vise.

Solution:

FBD:



$\circlearrowleft + \Sigma M_B = 0$

$\Leftrightarrow -F \times 5" - 69 lb \times 30" = 0$

$\rightarrow \boxed{F = -414 \text{ lb}}$

As the result, the force at point A should be $\boxed{414 \text{ lb}}$ to make the moment at point B.

A – 6: Deflection

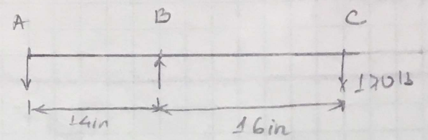
Phuc Chau | MET 495C Test | 04/10/2017 2/2

Given: The I-beam S3x5.7, with material A-36.

Find: Deflection of I-beam.

Solution:

FBD:



$\circlearrowleft \Sigma M_A = 0 \Leftrightarrow R_B \times 14 - 170 lb \times 30 in = 0$

$\Leftrightarrow \boxed{R_B = 364.29 lb}$

$+\uparrow \Sigma F_y = 0 \Leftrightarrow -R_A + R_B - 170 lb = 0$

$\Leftrightarrow R_A = 364.29 - 170 lb \Leftrightarrow \boxed{R_A = 194.29 lb}$

+ $I_x = 2.52\ in^4$

$S_x = 1.68\ in^3$

$E = 29 \times 10^6\ psi$

* Deflection:

$$Y = \frac{-PL^3}{3EI}$$

$$Y = \frac{-170 lb \times (16 in)^3}{3 \times 29 \times 10^6 psi \times 2.52 in^4}$$

$$\boxed{Y = 0.00318\ in}$$

A – 7: Stress Bending

Phuc Chau | ME1495C: Test | 04/10/2017

Given: - The I-beam ($S3 \times 5.7$) hold a 170 lb bending a force acting at the end.

- Length = 16 in.
- Safety factor = 1.5

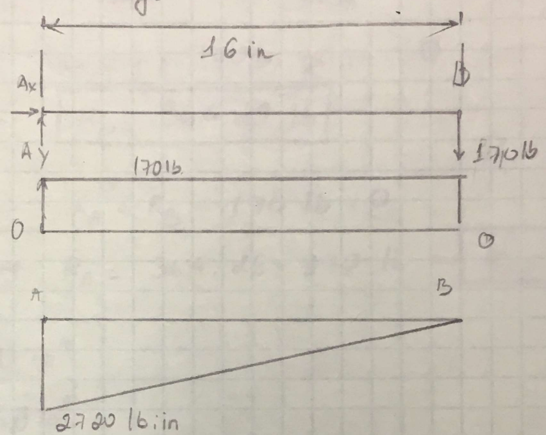
Find: Maximum bending stress,

Solution:

FBD.

V (lb)

M (lb.in)



$+\uparrow \Sigma F_y = 0 \Leftrightarrow A_y - 170 \text{ lb} \Leftrightarrow A_y = 170 \text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0 \Leftrightarrow A_x = 0$

$M_A = F \times d = (170 \text{ lb})(16 \text{ in}) = 2720 \text{ lb.in}$

\+ Finding normal bending stress:

$\sigma = \frac{M}{S}$ (Eq. 3-24, pg. 102, Mott text book)

$S = 1.68$ (Appendix table 15-10, pg. 757)

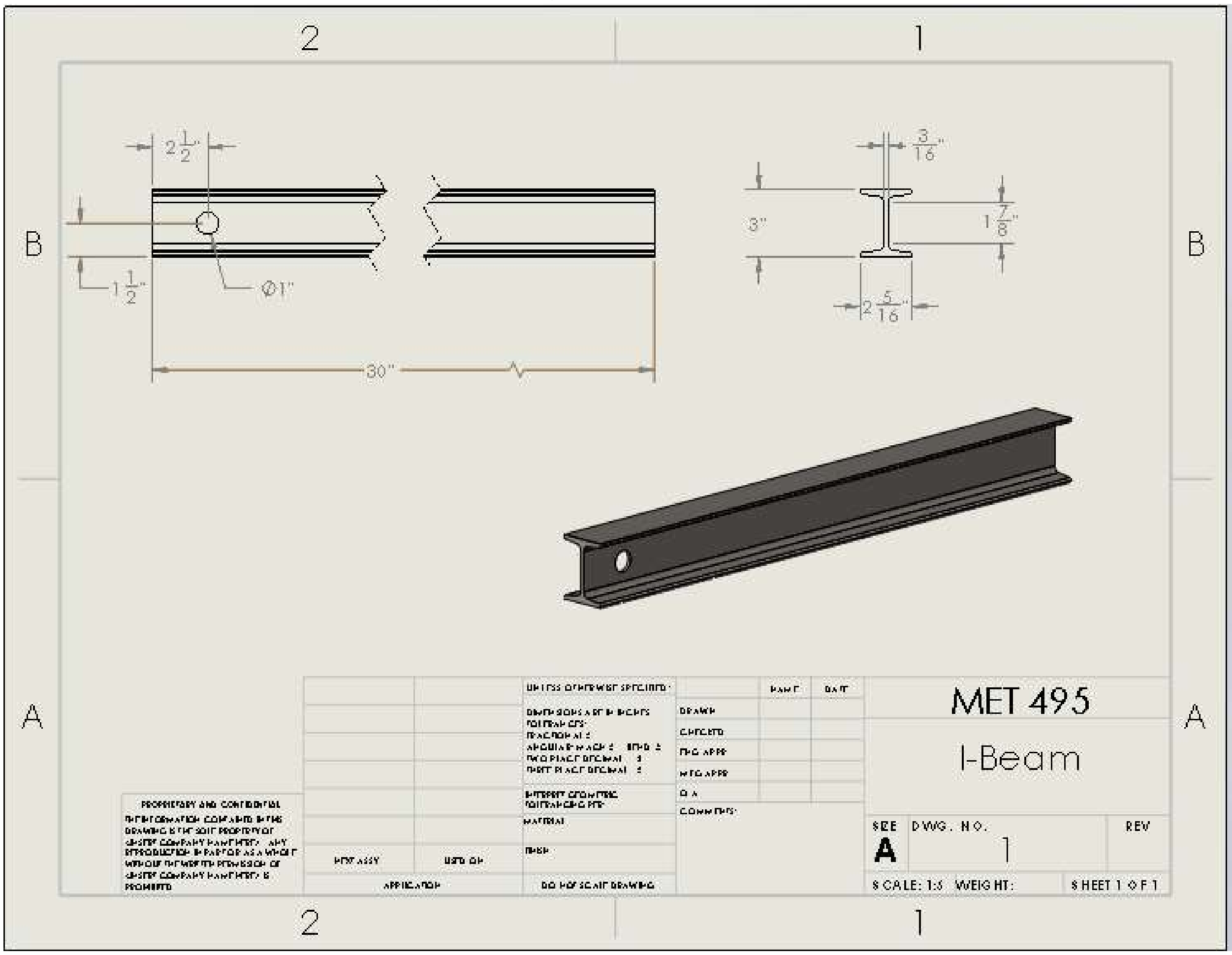
$$\sigma = \frac{2720 \text{ lb.in}}{1.68 \text{ in}^3} = \boxed{1619.05 \text{ psi}}$$

$$\sigma_{design} = S.F. \times \sigma = 1.5 \times 1619.05 \text{ psi}$$

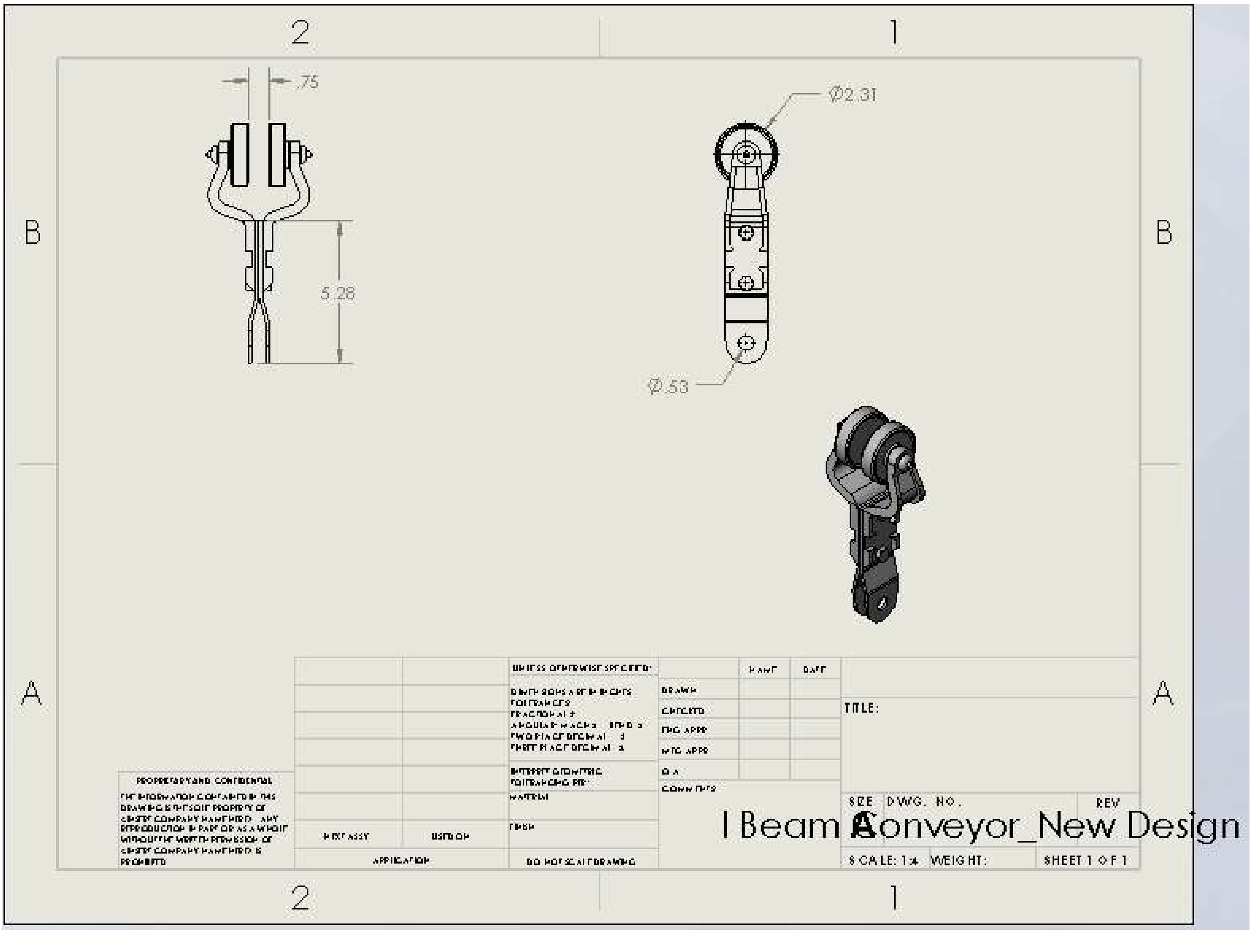
$$\boxed{\sigma_{design} = 2428.58 \text{ psi}}$$

Appendix B – Drawings

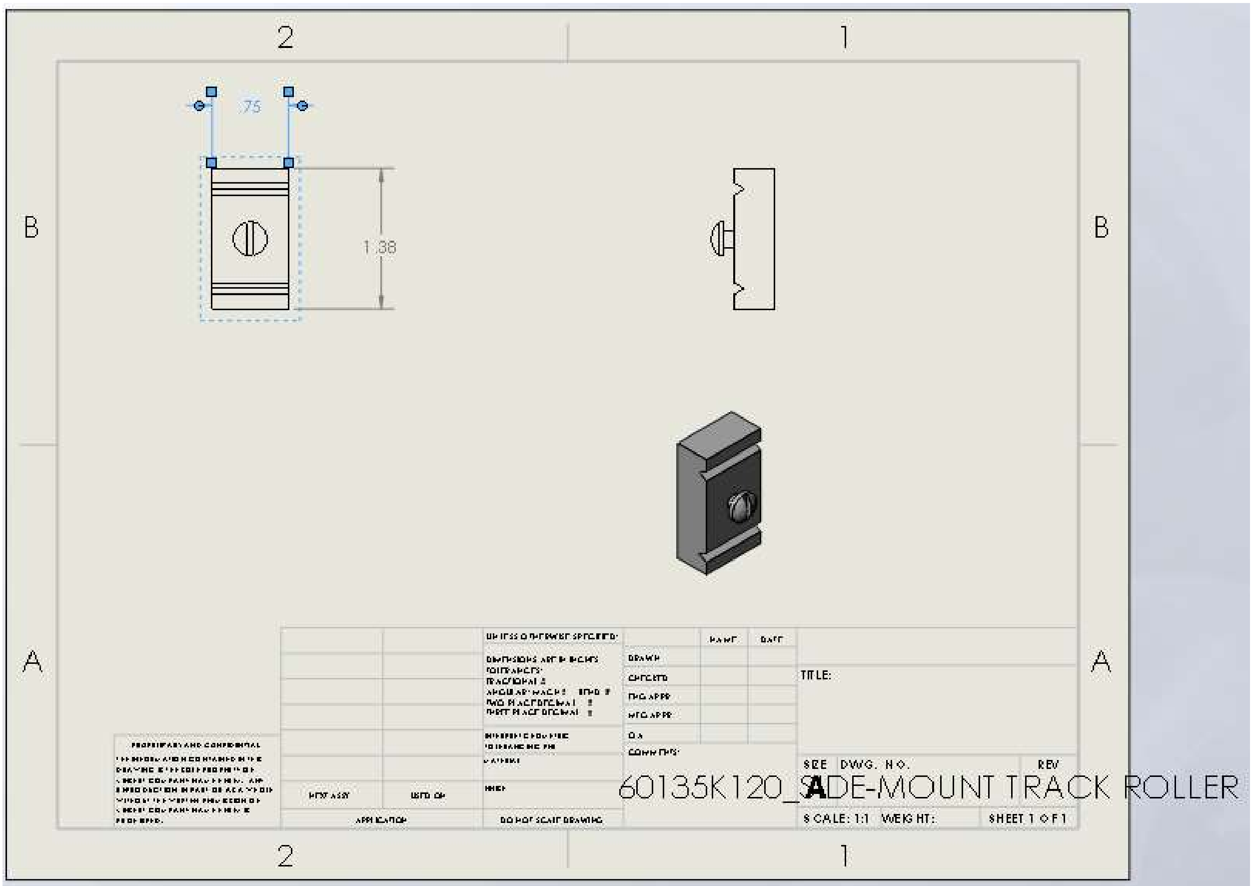
B – 1: Standard I Beam (S3 x 5.7)



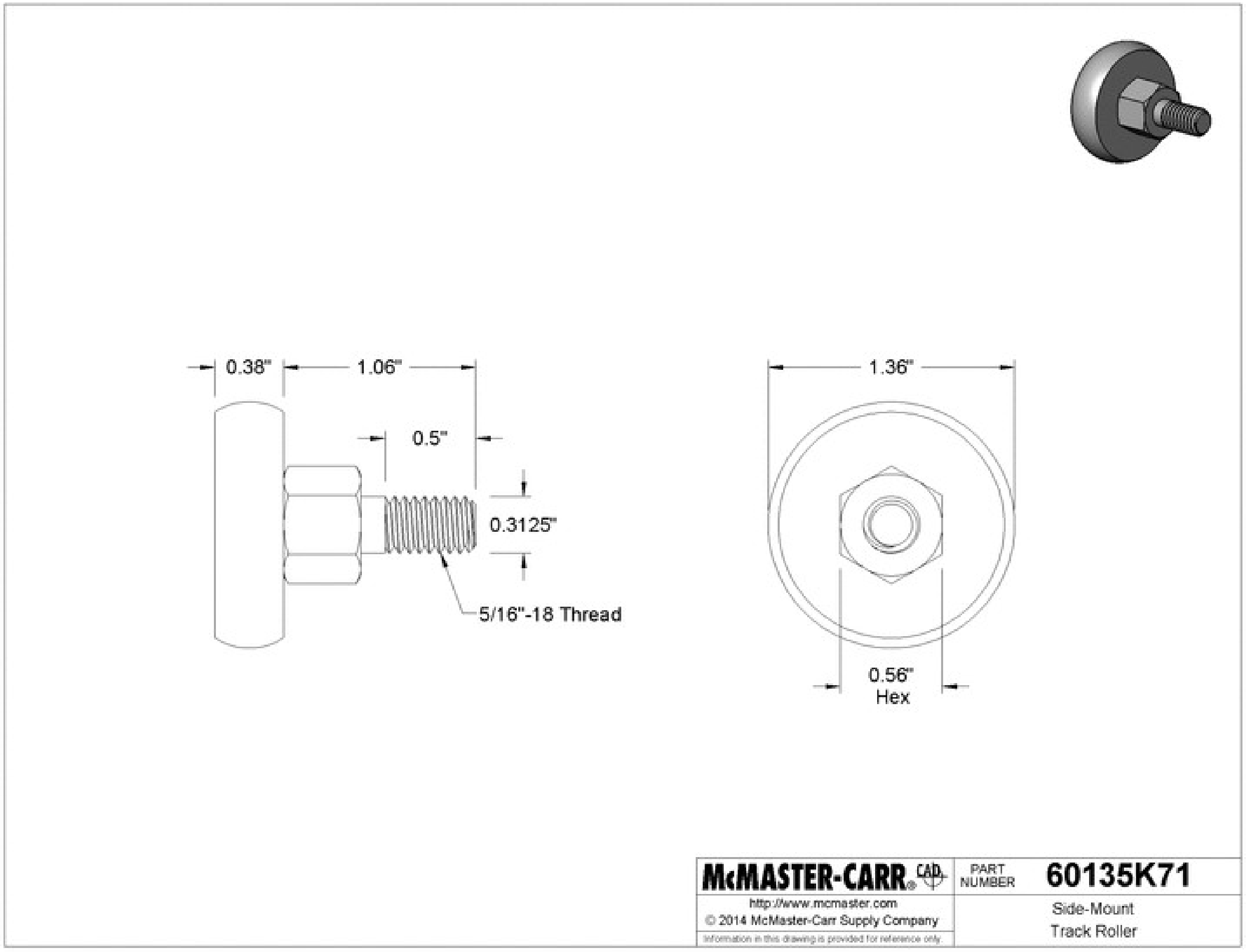
B – 2: I – Beam Conveyor



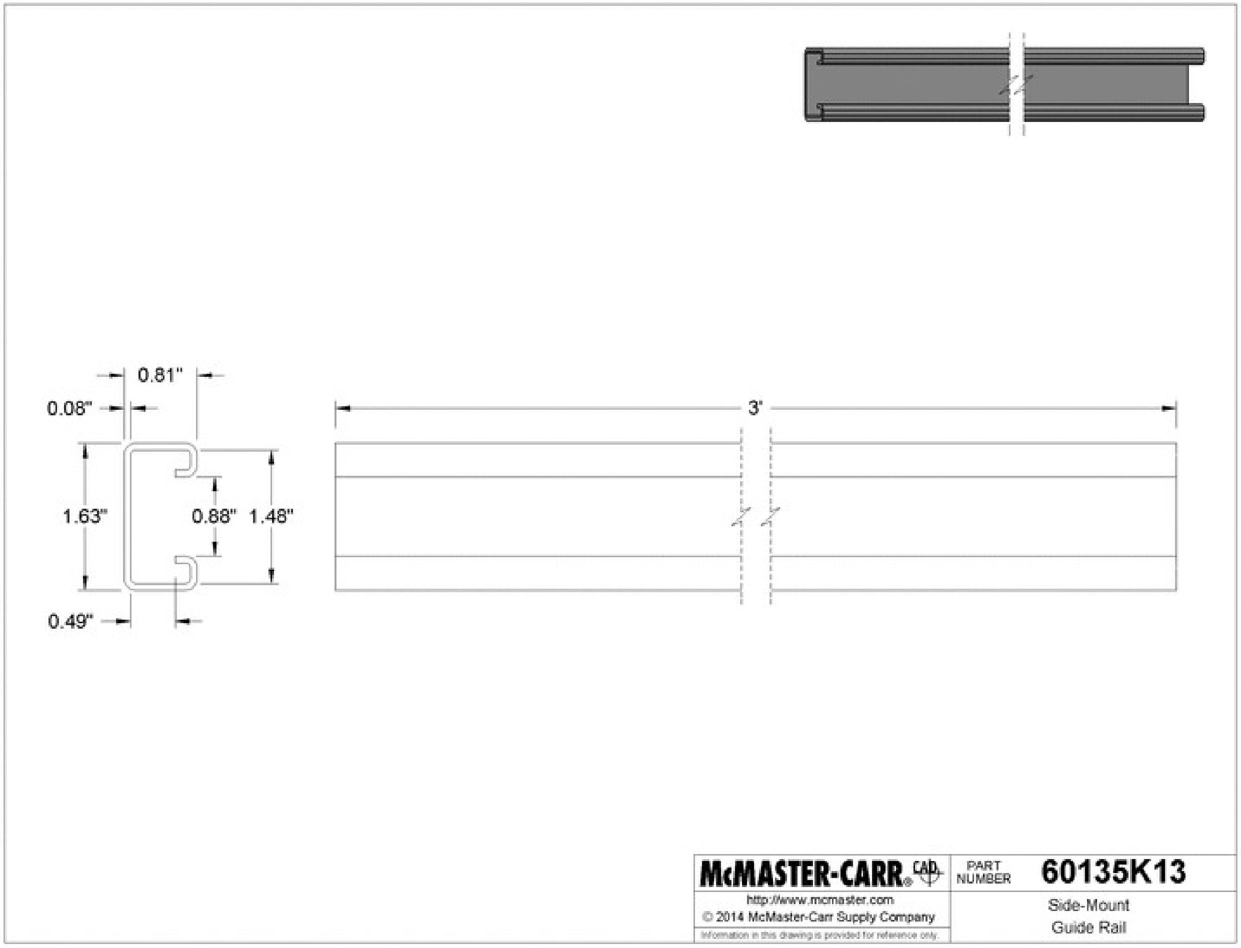
B – 3: Side Mount Track Roller



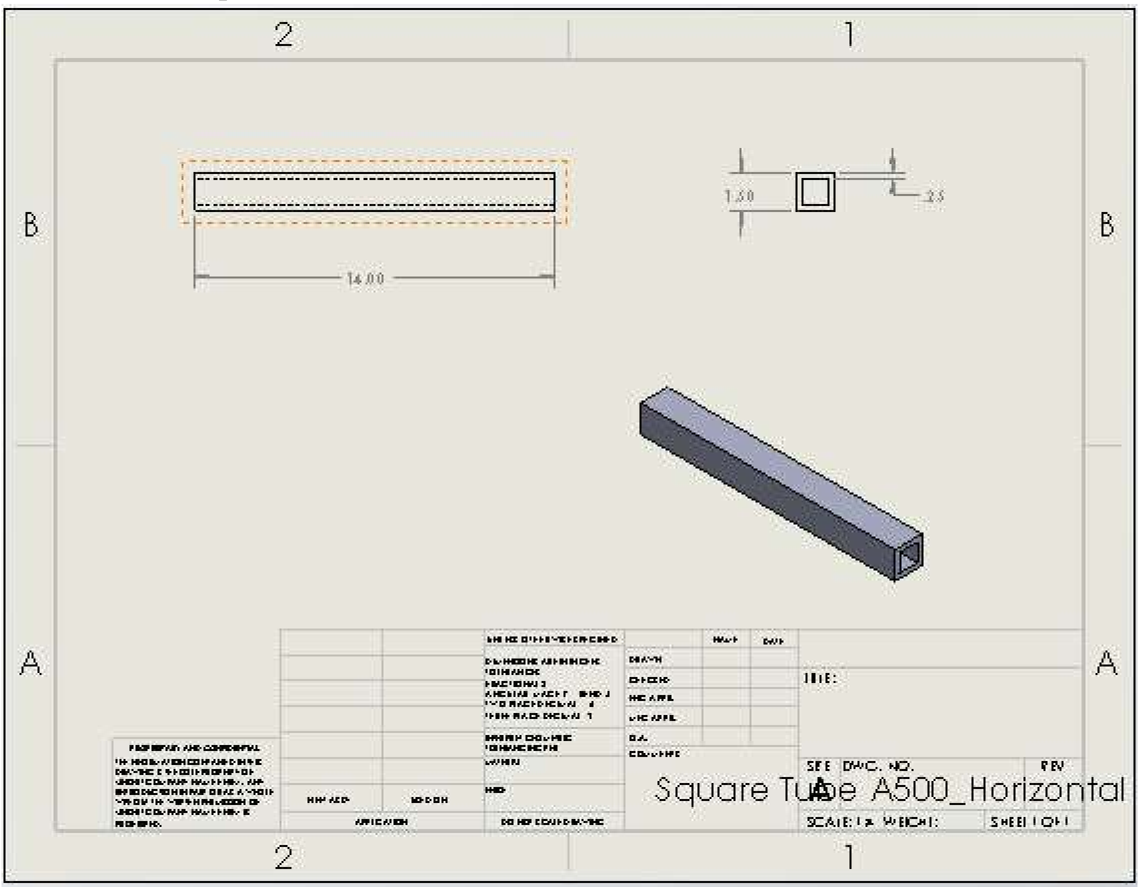
B – 4: Side Mount Track Roller



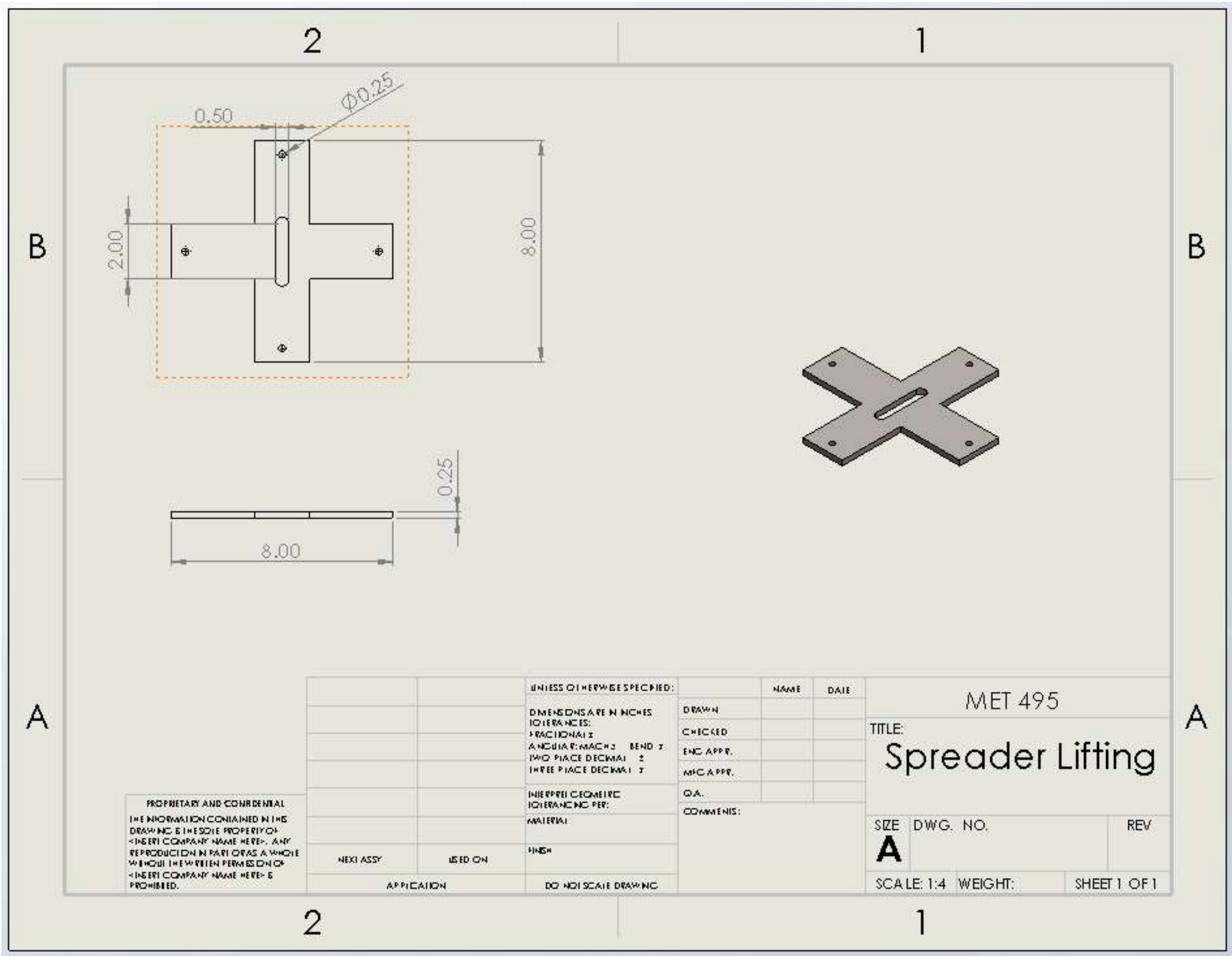
B – 5: Steel Side Mount Track Roller



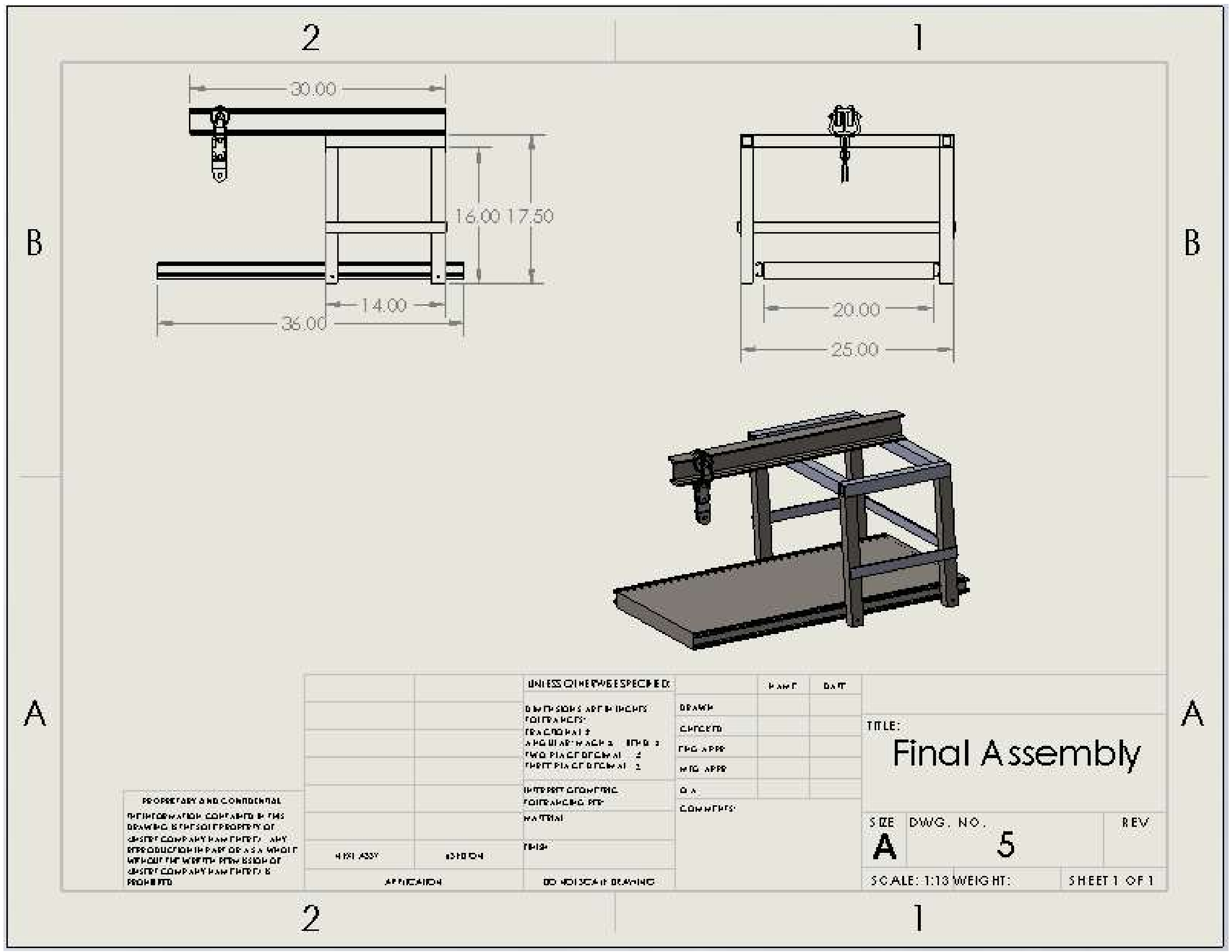
B – 6: Square Tube



B -7 Spreader Lifting



B – 8: Complete Assembly Project



Appendix C – Parts List

	Project: Sliding Part for the Lifting Arm Table			By	Phuc Chau		
No	Description	Quantity	Price	Total Price	Part Number	Length	Source
1	Standard I Beam S3x3 Depth, 3/16 thick	1		$ 30.29		2.5ft	Haskins Steel
2	Square Tube 1.5x1.5x1/4"	1		$ 68.27		12ft	Haskins Steel
3	Flat Bar (1/4x1-1/4)	1		$ 7.94		5ft	Haskins Steel
4	Overhead I-Beam Conveyor Component	1	$ 39.97	$ 39.97	5920K24		Mc-Master Carr
5	Steel Side-Mount Track Roller, 300lb capacity	2	$ 35.52	$ 71.04	60135K13		Mc-Master Carr
6	End Stop Side-Mount Track Roller	4	$ 3.76	$ 15.04	60135K12		Mc-Master Carr
7	Side-Mount Track Roller	4	$ 20.04	$ 80.16	60135K71		Mc-Master Carr
8	Tax	1		$ 8.73			
9	Shipping Fee	1		$ 17.66			
	Total	16		$ 339.10			

Appendix D – Budget

	Project: Sliding Part for the Lifting Arm Table			By	Phuc Chau		
No	Description	Quantity	Price	Total Price	Part Number	Length	Source
1	Standard I Beam S3x3 Depth, 3/16 thick	1		$ 30.29		2.5ft	Haskins Steel
2	Square Tube 1.5x1.5x1/4"	1		$ 68.27		12ft	Haskins Steel
3	Flat Bar (1/4x1-1/4)	1		$ 7.94		5ft	Haskins Steel
4	Overhead I-Beam Conveyor Component	1	$ 39.97	$ 39.97	5920K24		Mc-Master Carr
5	Steel Side-Mount Track Roller, 300lb capacity	2	$ 35.52	$ 71.04	60135K13		Mc-Master Carr
6	End Stop Side-Mount Track Roller	4	$ 3.76	$ 15.04	60135K12		Mc-Master Carr
7	Side-Mount Track Roller	4	$ 20.04	$ 80.16	60135K71		Mc-Master Carr
8	Tax	1		$ 8.73			
9	Shipping Fee	1		$ 17.66			
	Total	16		$ 339.10			

The total cost assumption is $339.10 for the project.

Appendix E – Schedule

E – 1: Fall Schedule

Schedule for Senior Project																			
Project Title:	Lifting Arms Hydraulic			From:	September 21st 2016				To:	May 17th 2017									
Name:	Phuc Chau																		
		Duration (hours)		September				October				November				December			
Task	Description	Estimation	Actual	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Proposal																		
a	Outline	1	2																
b	Introduction	2	3																
c	Design																		
d	Analysis																		
e	Method																		
f	Testing																		
g	Budget																		
h	Discussion																		
i	Conclusion																		
	Total																		
2	Manufacturing																		
3	Testing																		

E – 2: Winter Schedule

Senior Project Winter Quarter 2017

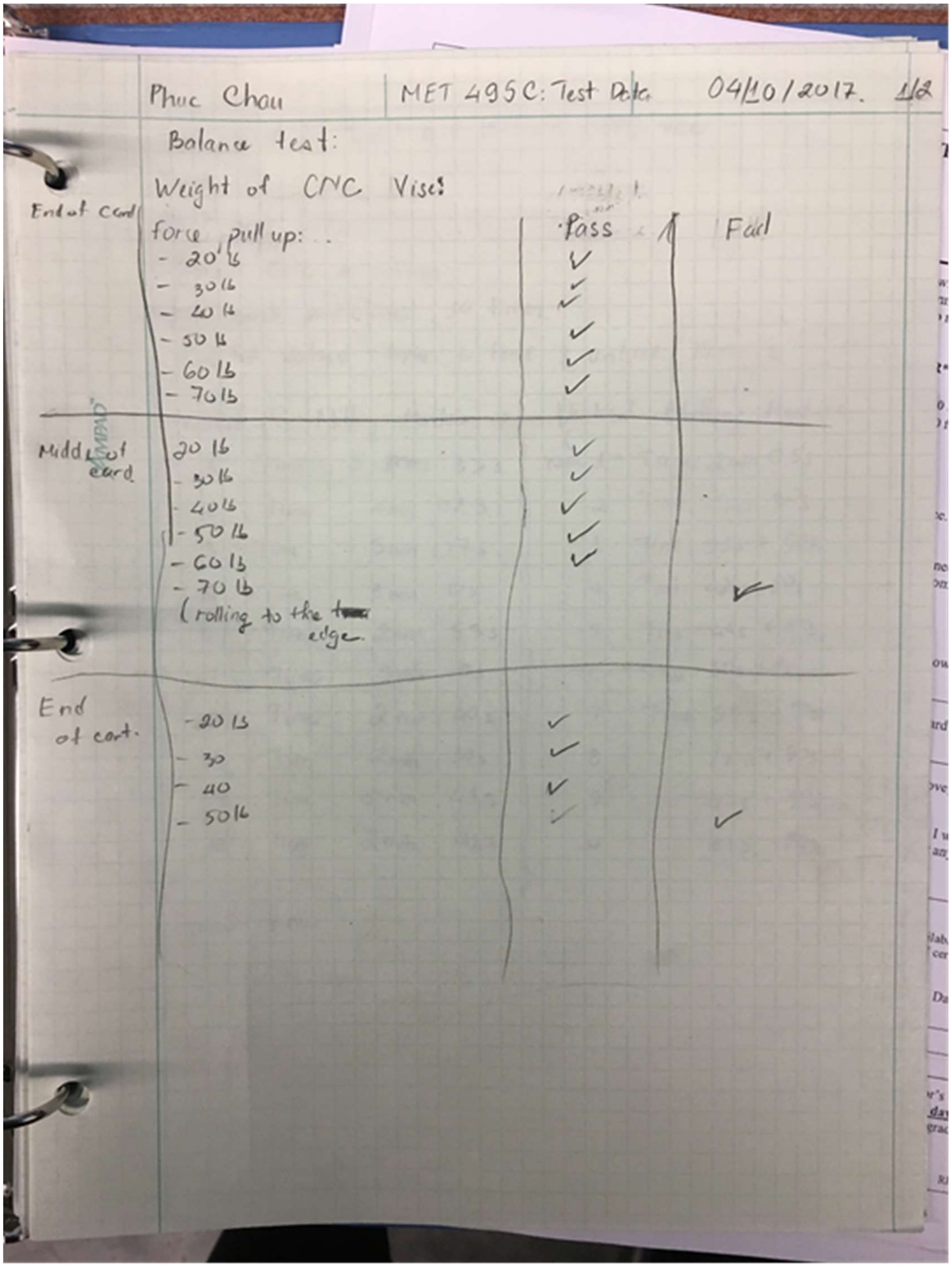
Project:	Sliding Part for Lifting Arm Table	By	Phuc Chau			Date: 01/23/2017								Predict	Actual
		January				February				March				Hours	Hours
Task	**Description**	Week 01	Week 02	Week 03	Week 04	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 1	Wk. 2	Wk. 3	Wk. 4		
1	**Design**														
a	Re-edit design													3	1.25
b	Working on standard draws													3	4
c	Geting recommendations and redesign														
d	Making Parts list sheet													1	2
e	Making Price Sheet													1	1
f	Getting approved by suppliers													0.5	0.5
2	**Order Material**														
a	Ordering Material														
b	Making Set up Sheets													2	1
c	Getting Recommendations from set up													2	2
d	Ordering tools if can't have in shops													2	0
3	**Manufacturing**														
a	Cuting parts														
	i. Cuting the Square Tube													2	2
b	Welding parts														
	i. Welding Square Tube together													3	3.5
	ii. Welding I-Beam with the frame													3	2.5
	iii. Wellding Side-Mount Track Roller													2	1
c	Drilling holes														
	i. Drilling hole on Square tube													2	3
	ii. Drilling hole on I-Beam													1	1
d	Assembly parts together														
	i. Put I-Beam Conveyor with I-Beam													0.5	1
	ii. Putting the frame with the channel													1	0.5
4	**Proposals and Website**														
a	Edit Proposal														
	i. Upload Calculation													2	5
	ii. Upload draws													2	5
	iii. Update Proposal													5	15
b	Upload some information to website													15	15
												Toal		53	66.25

E – 3: Spring Schedule

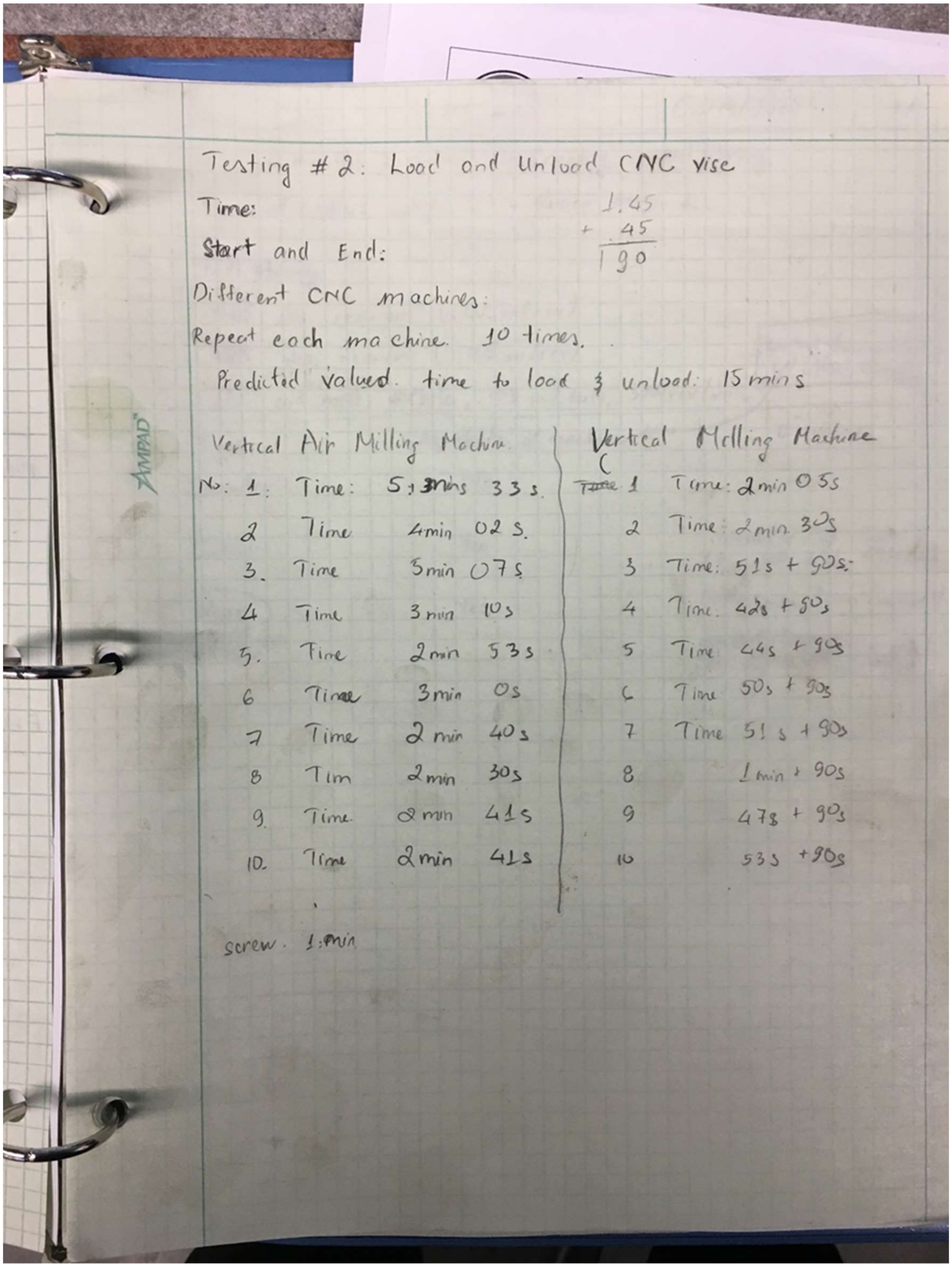
Project	Sliding Part for Lifting Arm Table	By	Phuc Chau				Date: 04/04/2017							Predict	Actual
		April				May				June					
Task	Description	Week 01	Week 02	Week 03	Week 04	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 1	Wk. 2	Wk. 3	Wk. 4		
1	**Testing Method**														
	a. Test Plan													2	3
	b. Test Demo 1													5	3
	c. Test Demo 2													5	6
	d. Test Report													3	4
	e. Machine the Lifting Spreader Bar													6	6
	f. Test Report													10	10
	g. Collecting data for Test demo 2													3	3
	h. Filming Testing 02													2	0.5
2	**PSR**														
	a. Final Report to Scholarwork													5	6
	b. Jump Drive													5	6
	c. PSR 01													1	1
	d. PSR 02													1	1
	e. PSR 03													1	1
	f. PSR 04													1	1
	g. PSR 05													1	1
	h. PSR 06													1	1
	i. PSR 07													1	1
	j. PSR 08													1	1
	k. PSR 09													1	0.5
	l. PSR 10													1	0.5
3	**FE Exam**														
	a. Math, Statistics and Probability													8	4
	b. Fluid, Thermo, and Heat Transfer													8	2
	c. Statics, Strength of Material, Dynamics													8	1
	d.Material and Engineering Econmics													8	0
	e. Mechanical Design, Ethics													8	1
	f. Electrics, and Instruments													8	0
	g. FE Response													0.5	0.25
4	**Website**														
	a. Web 01													5	5
	b. Web 02													5	6
5	**Final Report**														
	a. Abstract													2	1
	b. Introduction edition													2	2
	c. Methodology edition													2	3
	d. Result editition													2	3
	e. Conclustion edition													2	4
	f. Appendix and Others													2	4
6	**SOURCE**														
	a. Abstract													2	6
	b. Poster Making													2	4
	c. Presentation in SOURCE on 05/18													2	2
7	**Presentation**														
	a. Making Presentation Slide Shows													2	3
	b. Practicing													2	1
													Toal		136.5	108.8

Appendix F – Testing Data

F – 1: Test 01 Data Collected



F – 2: Test 02 Data Collected



Testing # 2: Load and Unload CNC vise

Time:

Start and End:

Different CNC machines:

Repeat each machine 10 times.

Predicted valued. time to load & unload: 15 mins

$$\begin{array}{r} 1.45 \\ + \ .45 \\ \hline 190 \end{array}$$

Vertical Air Milling Machine			Vertical Milling Machine	
No: 1.	Time:	5, 3mins 33 s.	1	Time: 2min 05s
2	Time	4min 02 s.	2	Time: 2min 30s
3.	Time	3min 07s	3	Time: 51s + 90s
4	Time	3 min 10s	4	Time: 42s + 90s
5.	Time	2min 53s	5	Time 44s + 90s
6	Time	3min 0s	6	Time 50s + 90s
7	Time	2 min 40s	7	Time 51 s + 90s
8	Tim	2min 30s	8	1 min + 90s
9.	Time	2 min 41s	9	47s + 90s
10	Time	2min 41s	10	53s + 90s

screw. 1 min

F – 3: Test Grant Chart

Project:	Sliding Part for Lifting Arm Table	By	Phuc Chau				Date: 04//04/2017							Predict Hours	Actual Hours
		April				May				June					
Task	Description	Week 01	Week 02	Week 03	Week 04	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 1	Wk. 2	Wk. 3	Wk. 4		
1	**Testing Method**														
	a. Test Plan													2	3
	b. Test Demo 1													5	3
	c. Test Demo 2													5	
	d. Test Report													3	4
	e. Machine the Lifting Spreader Bar													6	6
	f. Test Report													10	
	g. Collecting data for Test demo 2													3	3
	h. Filming Testing 02													2	0.5
												Total hours		36	19.5

F – 4: Test Data summary

Name	Phuc Chau	MET 495		Date	4/21/17				
Subject:	Test #2	Load and Unload CNC Jaws							
Machine #1	Vertical Air CNC Milling Machine				Machine #2	Vertical CNC Milling Machine			
	Time (mins)					Time (mins)			
Trial 01	5.55		**Predict time**	15 mins	Trial 01	2.083		**Predict time**	15 mins
Trial 02	4.033				Trial 02	2.5			
Trial 03	5.117				Trial 03	2.35			
Trial 04	3.167				Trial 04	2.2			
Trial 05	2.883				Trial 05	2.233			
Trial 06	3				Trial 06	2.333			
Trial 07	2.667				Trial 07	2.35			
Trial 08	2.5				Trial 08	2.5			
Trial 09	2.683				Trial 09	2.283			
Trial 10	2.683				Trial 10	2.383			
Average	**3.4283**	mins			Average	**2.3215**	mins		
	3 mins 30 s					**2 mins 20 s**			

Appendix G – Testing Report

Test Report

The Balancing Test and the Load and Unload the Vise Test

Introduction

Requirement: The purpose of this report is to build a device that can be installed to the hydraulic lifting cart to help students work easily on the CNC machine. The device is required to lift up variable sizes and shapes of CNC bases to the CNC milling table. Because of that, the main purpose of testing device is focused on balance of cart and load and unload the CNC bases to the shelves in the machine shop. Balancing test is applied as the first test.

The second test is applied on the device is the load and unload the CNC vise test. To pass the test requirement, the device must be able to get the CNC vise on the shelve and load to the CNC table in the machine shop.

Parameter of interest: The test is decided to test the balance of device to reduce the risk of accident when it's used in the machine shop. From the test, the tester will lift up the cart handle by certain amount of different forces when it's carried on the CNC jaws.

Predicted performance: The predicted performance of this test is around 50 lbs. because the moment force from calculation causes fatigue is 50lbs.

The second test predicts the device can be load and unload the vise within 15 mins because the total lab hours is two hours. So, fifteen minutes will take one eighth of lab times which is appropriate for a set up time.

Method/Approach

Summary/ Overview: The main purpose of the test is finding the heavies weigh that cause the device stiff over and fall of the CNC jaws. Also, the device should be tested for safety.

Specify time, duration: The assume time to finish the test is an hour.

Place: The device is tested at the machine shop, Hogue Hall because it has all equipment to take the test and reduce the risk of accident.

Resources needed: Professor Pringle gave recommendations for research, and Mr. Burvee, lab support instructor, provides lab equipment and recommendation for lab.

Risk, safety, evaluation readiness: When the jaw is hanging on the device to do the test. The device requires to park next to the table in case the jaws drops by stiffness.

Test Procedure

Summary/ overview: The main purpose of the test is finding the heavies weigh that cause the device stiff over and fall of the Kurt CNC vise. Also, the device should be tested for safety.

Specify time, duration: The actual test is taken 3 hours because it was needed to fix the lifting arm. Under the I-beam is welding, the square lifting spreader was built to carry multiples sizes of CNC jaws.

Place: The device is tested at the machine shop, Hogue Hall because it has all equipment to take the test and reduce the risk of accident.

Resources needed: Professor Pringle gave recommendations for research, and Mr. Burvee, lab support instructor, provides lab equipment and recommendation for lab.

Specific action to complete the test

Procedure Test 01

1. Step 01: drive the cart to the shelve and park perpendicular with the shelve
2. Step 02: Use your foot to step on the paddle to raise up the table until the wanted position.
3. Step 03: Use ½ inch helix bolts placed next to the CNC Milling machine
4. Step 04: Thread the bolts to hole from the CNC vise.
5. Step 05: Steps on the paddle and lift up the jaws
6. Step 06: Push back the cart and release oil back to reservoir
7. Step 07: Drive the cart to the table next to the gear making machine and park it perpendicular to the table.
8. Step 08: Use paddle to lift up the surface table same height as the table
9. Step 09: Use electric scale and hook it to the handle
10. Step 10: Pull up the scale in different amount of forces (10lbs, 15lbs, 20 lbs, 25 lbs, 30 lbs, …,) until the cart's wheels fall off the ground.
11. Step 11: Record data of weights
12. Step 12: Repeat step 09 to step 10 when put the frame rolling different locations in the cart.

Procedure Test 02

13. Step 01: drive the cart to the shelve and park perpendicular with the shelf
14. Step 02: Use your foot to step on the paddle to raise up the table until the wanted position.
15. Step 03: Use ½ inch helix bolts placed next to the CNC Milling machine
16. Step 04: Thread the bolts to hole from the CNC vise.
17. Step 05: Steps on the paddle and lift up the jaws
18. Step 06: Push back the cart and release oil back to reservoir

19. Step 07: Drive the cart to the CNC machine and park it perpendicular to the table.
20. Step 08: Use paddle to lift up the surface table same height as the CNC table
21. Step 09: Slide the frame on the table
22. Step 10: Release the oil brake on the cart to make the table lower than the CNC.
23. Step 11: The CNC vise lies on the CNC table
24. Step 12: Unscrew helix bolts and pull back the cart

Risk, safety, evaluation readiness: The cart must be park perpendicular to the table because if the jaw drops, it will drop on the table to reduce to risk of damage the jaws and floor

Discussion:

1. **Balance Test**

Position	Force Pulls up	Pass	Fail
Beginning of the cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb	x	
	60 lb	x	
	70 lb	x	
	80 lb	x	
Middle of the Cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb	x	
	60 lb	x	
	70 lb		x
	80 lb		x
End of the cart	20 lb	x	
	30 lb	x	
	40 lb	x	
	50 lb		x
	60 lb		x
	70 lb		x
	80 lb		x

The table above shows data taken when lift different amount of force to find the stiffness of the cart. Pass means the frame does not roll. Fail means the frame rolls and the jaws drops on the table.

The most difficult in the test is lifting the scale up by my hand. The scale handle is small and hard to hold the right force apply to the handle. As the result, the force apply can't be correct exactly.

2. Time Performance

For the second test, the cart is tested by load and unload the CNC vise. The cart performs well, so to make raise up another requirement, the cart should be load and unload less tha fifteen minutes. The data below is showed the time performance of load and unload CNC vise to CNC table from different CNC machine and shelves location in the machine shop.

Name	Phuc Chau	MET 495		Date	4/21/17				
Subject:	Test #2	Load and Unload CNC Jaws							
Machine #1	Vertical Air CNC Milling Machine				Machine #2	Vertical CNC Milling Machine			
	Time (mins)					Time (mins)			
Trial 01	5.55		**Predict time**	15 mins	Trial 01	2.083		**Predict time**	15 mins
Trial 02	4.033				Trial 02	2.5			
Trial 03	5.117				Trial 03	2.35			
Trial 04	3.167				Trial 04	2.2			
Trial 05	2.883				Trial 05	2.233			
Trial 06	3				Trial 06	2.333			
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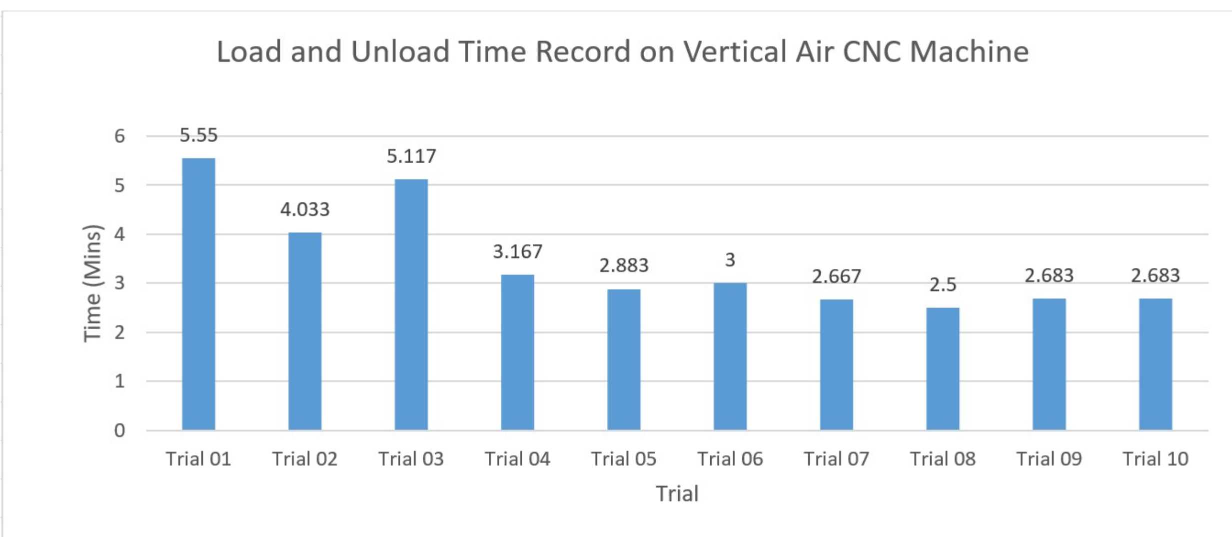
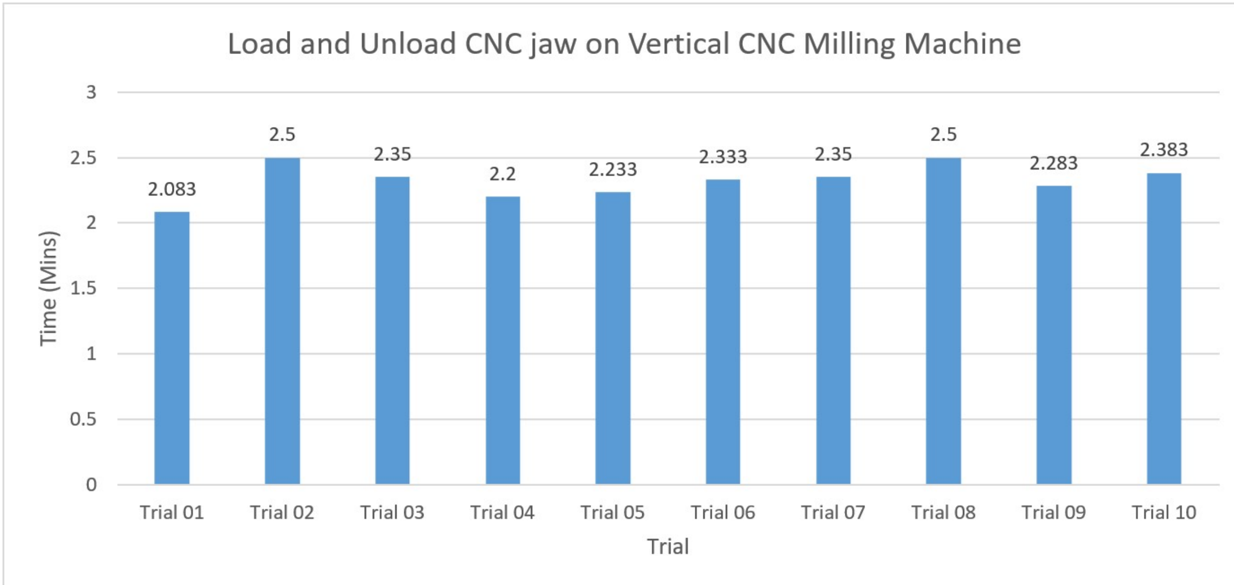
Trial 09	2.683				Trial 09	2.283			
Trial 10	2.683				Trial 10	2.383			
Average	**3.4283**	mins			Average	**2.3215**	mins		
	3 mins 30 s					**2 mins 20 s**			





Deliverables

Parameter values: In the testing, the maximum force can apply on the scale is 80 lbs. When 80 lbs. is applied to the cart, it not moving or stiff over, so the force can be applied more than 80 lbs.

Calculated values: According to calculation, to cause the moment at the wheel of the cart and make it stiff over, the total force should be 414 lbs. See appendix for calculation.

Success criteria values: The estimate force for this test is about 80lbs, and it is passed the requirement. As the result, the test is successful.

Conclusion:

In summary, the testing 01 is successful because the predicted force applied is only 40 lbs. because it doesn't require much force to lift up the cart. Mostly people use to roll the cart around the machine shop. 40 lbs. is the small amount of force could be accidently happen when users lift up the cart and make it stiff over. In addition, the cart has a current heavy weight, so it can help the cart be balance itself even though there is force applied to lift up.

Appendix H – Resumes

Phuc Chau

Phuc.Chau@cwu.edu | (206) 739-9919 | PO Box 1661, Ellensburg, WA – 98926|
www.linkedin.com/in/phucchaucwu

OBJECTIVE:

Seeking Mechanical Engineering Entry Level

EDUCATION

Bachelor of Science in Mechanical Engineering Technology December 2017

Central Washington University, Ellensburg, WA

GPA = 3.6

SKILLS

Computer Skill: AutoCAD, Solid Work, Word, Excel, Power Point, Outlook

Engineering Related Skills

Manual Machining (lathe, mill, drill press, grinder, and belt sander)

Advance Machining (CNC programming, CNC Mill, and CNC Lathe)

Metallurgy (tested on hardness of material, understood ANSI and ISO standard)

Energy (Temperature, Heat Transfer Energy, Thermodynamics)

Language: Vietnamese, English

Leadership

Dean's List – 5 quarters 2013 – Present

International Merit Waiver Scholarship - 2 years 2015 - 2017

CWU Wildcat Nation Scholarship 2014-2015

Scholarship Award for Technology and Engineering Students 2010 - 2011

Activities

CWU Swim Club January 2015 – Present

- CWU Spring National Swim Team 2016

CWU ASME Club September 2015 – Present

- ASME Secretary Officer (2016-2017)

RELATED PROJECTS

3D – Modeling: phone case holding July 2014

- Designed the phone case on Solid Work Program, using all features studied in class
- Used the 3D printer to print out the project

Manual Machine: Paper Puncher Project — July 2014

- Read the project requirements
- Made different parts of the hole punch in lathe, mill, drill press, and grinder machine
- Measured parts of project to be accuracy

CNC Programming: Steel Hammer — December 2014

- Programmed the steel hammer on computer and got advised from instructor
- Used the CNC Mill on the steel hammer (chamfer, mill surface, drill hole)
- Used the CNC Lathe, making the holding part of the hammer

WORK EXPERIENCE

Math Tutor, CWU Learning Commons Center, Ellensburg, WA — April 2016 – Present

- Helping and encouraging students solving homework problems
- Working as a team, or individually
- Having a meeting with coordinator every week
- Using leadership skill at work

Student Assistant, Periodicals Department, CWU Library, Ellensburg, WA — June 2014 – Present

- Assisting students and faculties searching books, articles and/or journals
- Organizing and maintaining journals and article boundaries
- Answering phone call, making requests, and working on different projects
- Maintaining and working individually

Tutor, Athletics Academic Services, Ellensburg, WA — February – June 2016

- Helped athletic students working on homework problems
- Wrote reports and submitted to supervisor at the end of each time
- Hold a meeting at the end of quarter

Dining Student Staff, CWU Dining Services, Ellensburg, WA — October 2013- May 2014

VOLUNTEER EXPERIENCE

Open Door Health Clinic – Ellensburg, WA — June – September 2014

Center for Leadership and Community Engagement – Ellensburg, WA — April 2013 – June 2014

MAJOR COURSES TAKEN

- Computer Aided Design and Drafting (AutoCAD software – features, limitations, and dimensions)
- 3-D Modeling (Solid Work Program)
- Basic Machining (lathe, mill, and drill dress) and Advance Machining (CNC Programming)
- Statics, Strength of Material and Applied Strength of Material
- Metallurgy/Materials and Processes (Ferrous and Non-Ferrous metals, and Alloys)
- Thermodynamics, Fluid Dynamics, Heat Transfer and Energy Engineering
- Engineering Dynamics
- Engineering Project Cost Analyzed
- Hydraulics and Pneumatics
- Mechanical Design

CERTIFICATIONS

How to Be an Exemplary Employee, CWU Student Employment Leadership	December 2015
CWU Preventing Employment Discrimination and Preventing Sexual Harassment	September 2016